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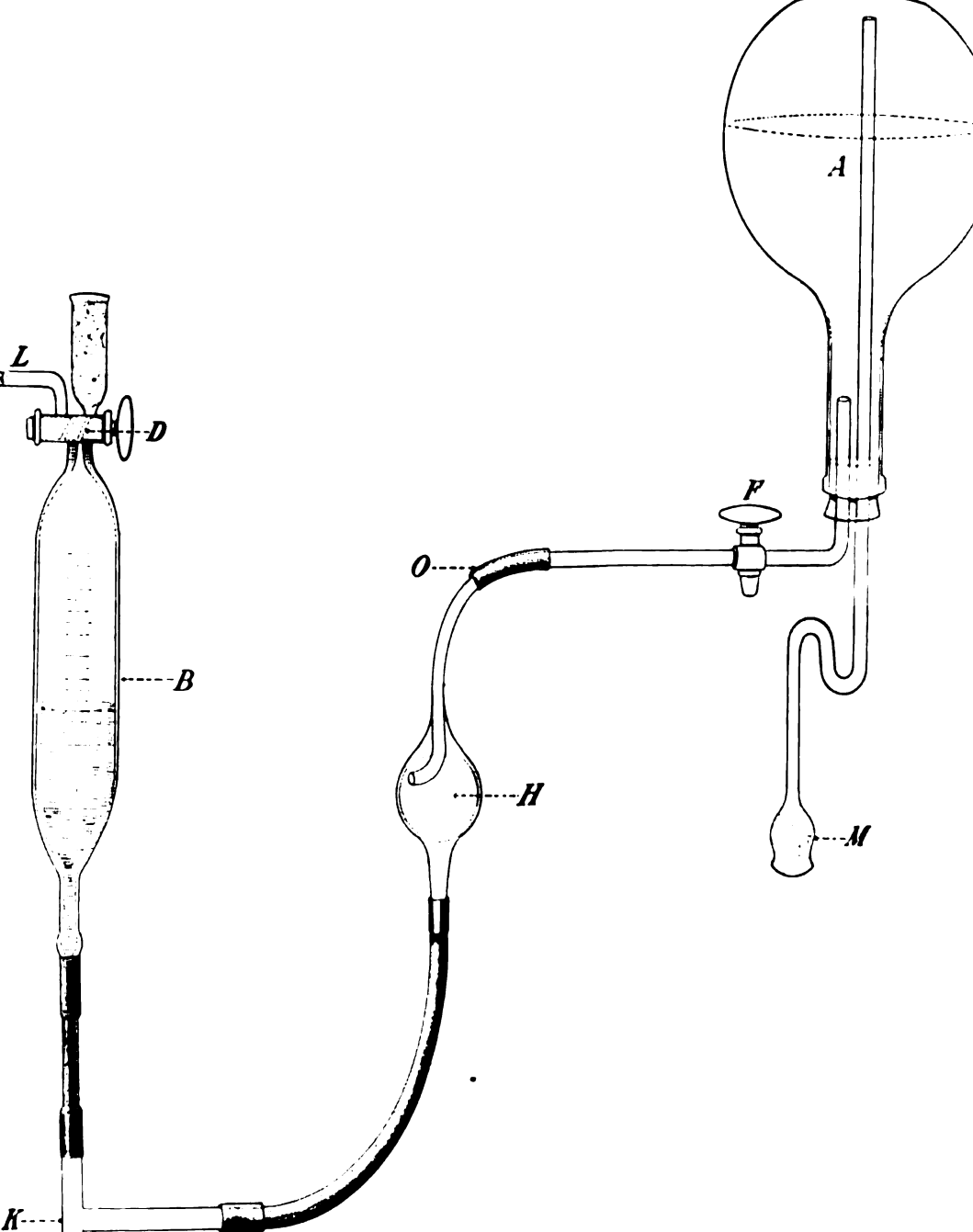
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# Bulletin

Hawaiian Sugar Planters' Association.  
Experiment Station, Hawaiian Sugar Planters' Association



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**DIVISION OF AGRICULTURE AND CHEMISTRY**

**BULLETIN No. 19**

**REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION**

**Lysimeter Experiments**

**BY C. F. ECKART**

**HONOLULU, H. T.  
1906**

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REPORT OF WORK  
OF THE  
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OF THE  
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# Lysimeter Experiments

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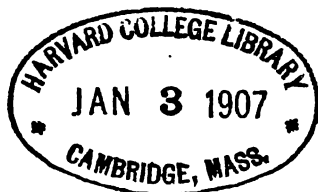
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1906



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## LETTER OF TRANSMITTAL

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To the Experiment Station Committee of the Hawaiian Sugar  
Planters' Association, Honolulu, T. H.

Dear Sirs:—I, herewith, submit for publication, as Bulletin  
No. 19 of the Division of Agriculture and Chemistry, the results  
from two series of lysimeter experiments conducted at the Experiment  
Station.

Yours very truly,

C. F. ECKART,

Director, Division of Agriculture and Chemistry.

Honolulu, T. H., September 26th, 1906.



# LYSIMETER EXPERIMENTS\*

By C. F. ECKART.

## FIRST SERIES.

The first series of tests described in this bulletin deals with the action of various nitrogenous fertilizer materials when applied to the Experiment Station soil, and results are given indicating the relative rate of nitrification, under similar conditions, of tankage, fishscrap, hoofmeal, sulphate of ammonia, and dried blood. The comparative readiness with which nitrogen, in these various compounds together with that in nitrate of soda, may be leached from the soil is considered, and data are presented bearing on the loss of lime following the application of sulphate of ammonia, nitrate of soda and dried blood.

Seven large tubs were converted into lysimeters in the manner described in Bulletin No. 8 (Reports for the Year 1902) when drainage experiments were conducted to note the solvent action of saline irrigation on various soil elements. Into each of these tubs were placed 188.16 pounds of soil containing 13.37% of water. The chemical analysis of this soil was as follows:

### ANALYSIS OF SOIL SAMPLE BY THE AGRICULTURAL METHOD.

(Hydrochloric acid, 1.115 Sp. Gr. used as solvent.)

	Per cent.
Moisture .....	8.52
Vol. Matter .....	9.69
Insol. Residue .....	31.82
Ferric Oxide .....	24.40
Alumina .....	16.40
Lime .....	1.37
Magnesia .....	4.77
Potash .....	.414
Soda .....	.525
Phosphoric Anhydride .....	.958
Sulphuric Anhydride .....	.051
Total .....	98.918

\* This bulletin is the first of a number to be published from time to time dealing with lysimeter experiments with different types of Hawaiian soils.

	Per cent.
Total Nitrogen .....	.157
Nitrate " .....	.003
Humus .....	2.50
Nitrogen in Humus, per cent. ....	5.60
Nitrogen in Humus, per cent soil....	.14

#### ASPARTIC ACID ANALYSIS.

(One per cent. solution of Aspartic Acid used as solvent.)

Moisture .....	7.28
Organic Matter .....	9.41
Silica .....	.1096
Lime .....	.3271
Magnesia .....	.2433
Ferric Oxide .....	.0040
Alumina .....	.0060
Sulphuric Anhydride .....	.0098
Chlorine .....	.0360
Potash .....	.0301
Soda .....	.0471
Phosphoric Acid .....	.0253

#### MECHANICAL ANALYSIS.

Loss on ignition .....	16.24
Coarse Grits .....	4.74
Fine Grits .....	4.49
Coarse Sand .....	2.70
Medium Sand .....	10.01
Fine Sand .....	30.76
Coarse Silt .....	16.10
Fine Silt .....	13.20
Clay .....	2.04
Total .....	100.28

In filling the tubs, 138 pounds of soil were first placed in each container. To the remaining 50 pounds required for each test, the various nitrogenous fertilizers were added and intimately mixed, the mixture then being added as a superincumbent layer to the soil already in the lysimeters. The material incorporated with the upper layer of soil in the case of the respective tubs were as follows:

Tub No. 5, Tankage .....	315 grams
Tub No. 6, Fishscrap .....	196 grams
Tub No. 7, Check .....	
Tub No. 8, Hoofmeal .....	137 grams
Tub No. 9, Nitrate of Soda .....	105 grams
Tub No. 10, Sulphate of Ammonia..	78 grams
Tub No. 11, Dried Blood .....	123 grams

The quantity of nitrogen in each of these substances was 16.3 grams, or 1 gram to each pound of dry matter in the soil.

The soils in the lysimeters were irrigated first at weekly intervals and subsequently at bi-weekly periods, the drainage being caught in galvanized iron containers and subjected to analysis. The amounts of water added and the drainage discharge for the separate irrigations are shown in the following tables, together with the dates of the different waterings:

Irrigation and Drainage.

No. of Irrigation	5		6		7		8	
	Irriga- tion Liters	Drainage Liters	Irriga- tion Liters	Drainage Liters	Irriga- tion Liters	Drainage Liters	Irriga- tion Liters	Drainage Liters
1	20	....	20	....	20	....	20	....
2	10	5.32	10	5.50	10	5.29	10	5.39
3	10	6.19	10	6.80	10	7.15	10	7.20
4	10	7.56	10	7.42	10	7.43	10	7.41
5	15	6.595	15	7.82	15	6.91	15	6.74
6	15	6.20	15	6.85	15	6.62	15	6.12
7	15	5.85	15	6.10	15	6.92	15	6.20
8	15	5.64	15	5.55	15	6.25	15	5.60
9	15	6.08	15	6.08	15	6.80	15	6.30
10	15	5.15	15	5.53	15	5.86	15	5.26
11	15	5.25	15	5.75	15	6.04	15	5.34
12	15	4.76	15	5.40	15	5.45	15	5.31
13	15	5.11	15	5.80	15	6.42	15	5.42
14	15	6.15	15	6.79	15	6.82	15	6.49
15	15	6.55	15	7.04	15	7.12	15	6.86
16	15	6.76	15	7.51	15	7.00	15	6.78
17	15	6.51	15	6.94	15	6.80	15	6.63
18	15	5.27	15	5.32	15	5.02	15	5.03
19	15	5.34	15	5.05	15	5.22	15	4.77
20	15	5.29	15	5.31	15	5.38	15	5.03
21	15	5.98	15	6.17	15	6.40	15	6.23
TOTAL	305	117.555	305	124.73	305	126.90	305	120.11



## Irrigation and Drainage.

No. of Irrigation	9		10		11	
	Irrigation Liters	Drainage Liters	Irrigation Liters	Drainage Liters	Irrigation Liters	Drainage Liters
1	20	....	20	....	20	....
2	10	6.20	10	5.65	10	5.78
3	10	7.31	10	7.17	10	7.27
4	10	7.61	10	7.56	10	7.40
5	15	7.45	15	6.38	15	7.19
6	15	6.44	15	6.74	15	6.72
7	15	6.30	15	6.25	15	6.00
8	15	5.75	15	5.58	15	5.88
9	15	6.00	15	6.25	15	6.00
10	15	5.27	15	5.53	15	5.43
11	15	5.77	15	5.25	15	5.43
12	15	5.31	15	5.08	15	5.35
13	15	5.65	15	5.50	15	5.65
14	15	6.45	15	6.32	15	6.64
15	15	7.24	15	6.96	15	7.03
16	15	7.24	15	7.25	15	7.10
17	15	7.14	15	7.03	15	6.32
18	15	5.67	15	5.33	15	5.01
19	15	5.86	15	5.39	15	4.73
20	15	5.99	15	5.38	15	4.93
21	15	7.43	15	6.62	15	6.04
Total	305	128.08	305	123.22	305	121.90

## Times at Which Soils In Lysimeters Were Irrigated.

Irrigation No.	Date of Irrigation	Irrigation No.	Date of Irrigation
1	March 14	12	July 25
2	March 21	13	Aug. 8
3	March 28	14	Aug. 22
4	April 4	15	Sept. 5
5	April 18	16	Sept. 19
6	May 2	17	Oct. 3
7	May 16	18	Oct. 17
8	May 31	19	Oct. 31
9	June 13	20	Nov. 14
10	June 27	21	Nov. 28
11	July 11		

The largest volume of water applied at any one time was for the first irrigation, when 20 liters or 2.94 inches were added. For the three succeeding irrigations, 10 liters or 1.47 inches were applied, and for subsequent irrigations 15 liters or 2.20 inches.

It is interesting to note at this place the large quantity of water draining away from each soil following what would be considered moderate irrigations under ordinarily plantation conditions. Where 2.2 inches of water were applied every two weeks, the average drainage from tub No. 7 (Check Experiment) was .92 inch, the soil (14 inches deep) only holding 1.28 inches or about 58% of the added water. The fact that the lysimeters were placed on a sheltered veranda and almost entirely protected from the sun and wind accounts in a large measure for the small evaporation which took place during the intervals between successive irrigations.

The amounts of water held by the soils in the several tubs, immediately preceding the respective irrigations, and likewise the average amounts held during the intervals between irrigations, were found by calculation to be very approximately as follows:

**Moisture of Soils Previous to Respective Irrigations, Showing  
Percentage of Saturation.**

Irriga- tion No.	5	6	7	8	9	10	11
	Tank- age	Fish- scrap	No Fer- tilizer	Hoof- meal	Nitrate of Soda	Sulph. of Ammonia	Dried Blood
1	34.68	34.68	34.68	34.68	34.68	34.68	34.68
2	85.77	86.32	85.68	85.97	88.44	86.77	87.16
3	88.41	90.26	91.34	91.49	91.82	91.37	91.72
4	92.58	92.15	92.18	92.12	92.73	92.58	92.10
5	74.44	78.17	75.39	74.88	77.04	73.78	76.25
6	73.24	75.22	74.51	73.00	73.97	74.88	74.81
7	72.17	72.94	75.42	73.24	73.55	73.40	72.62
8	71.53	71.26	73.39	71.41	71.86	71.35	72.26
9	72.57	72.57	75.06	73.55	72.62	73.39	72.62
10	70.04	71.20	72.21	70.37	70.41	71.20	70.90
11	70.35	71.86	72.75	70.62	71.93	70.35	70.90
12	68.83	70.80	70.96	70.53	70.53	69.84	70.65
13	69.92	72.02	73.91	70.87	71.56	71.12	71.56
14	73.09	75.04	75.12	74.13	74.00	73.60	74.58
15	74.31	75.79	76.03	75.24	76.40	75.77	75.77
16	74.94	77.22	75.67	75.00	76.40	76.43	75.84
17	74.18	75.49	75.06	74.54	76.10	75.77	73.60
18	70.41	70.57	69.66	69.69	71.63	70.60	69.62
19	70.62	69.74	70.26	68.89	72.20	70.77	68.76
20	70.47	70.53	70.75	69.68	72.60	70.75	70.76
21	72.57	73.15	73.85	73.33	76.98	74.51	72.75

Average Percentage of Saturation Between  
Respective Irrigations.

Interval Between Irrigations. Nos.		5	6	7	8	9	10	11
		Tank- age	Fish- scrap	No Fer- tilizer	Hoof- meal	Nitrate of Soda	Sulph. of Ammonia	Dried Blood
1 and 2	2	92.88	93.16	92.84	92.98	94.22	93.38	93.58
2 and 3	3	94.20	95.13	95.67	95.74	95.91	95.68	95.86
3 and 4	4	96.29	96.07	96.09	96.06	96.36	96.29	96.05
4 and 5	5	87.22	89.08	87.69	87.44	88.52	86.89	88.12
5 and 6	6	86.62	87.61	87.25	86.50	86.98	87.44	87.40
6 and 7	7	86.08	86.47	87.71	86.62	86.77	86.70	86.31
7 and 8	8	85.76	85.63	86.69	85.70	85.93	86.67	86.13
8 and 9	9	86.28	86.28	87.53	87.77	86.31	86.69	86.31
9 and 10	10	85.02	85.60	86.10	85.18	85.20	85.60	85.45
10 and 11	11	85.17	85.93	86.37	85.31	85.96	85.17	85.45
11 and 12	12	84.41	85.40	85.48	85.26	85.26	84.92	85.32
12 and 13	13	84.96	86.01	86.95	85.43	85.78	85.56	85.78
13 and 14	14	86.54	87.52	87.56	87.06	87.00	86.80	87.29
14 and 15	15	87.15	87.89	88.01	87.62	88.20	87.88	87.88
15 and 16	16	87.47	88.61	87.83	87.50	88.20	88.21	87.92
16 and 17	17	87.09	87.74	87.53	87.27	88.05	87.88	86.80
17 and 18	18	85.20	85.28	84.83	84.84	85.81	85.30	84.81
18 and 19	19	85.31	84.87	85.13	84.44	86.10	85.38	84.38
19 and 20	20	85.23	85.26	85.37	84.84	86.30	85.37	85.38
20 and 21	21	86.28	86.57	86.92	86.66	88.49	87.25	86.37
Average		87.25	87.80	87.97	87.51	88.06	87.75	87.62

Having noted the conditions under which these tests were conducted, it will be of interest to observe the extent to which nitrogen in the form of nitrates appeared in the drainage from the several tubs following the different irrigations. This will enable us to form an idea with respect to the relative rate of nitrification of the materials added to the soils in tubs Nos. 5, 6, 8, 10 and 11. An indication will also be afforded of the comparative readiness in which the nitrogen from various nitrogenous fertilizers may be lost from soils of a similar character, where a high moisture content is maintained and a periodic and copious discharge of drainage water follows the application of water for irrigating purposes. The nitrogen in the form of nitrates which was carried into the drainage receivers was found to be as follows :

Nitric Nitrogen in Drainage.  
Grams.

Irriga- tion	5	6	7	8	9	10	11
	Tank- age	Fish- scrap	Check	Hoof- meal	Nitrate of Soda	Sulphate of Ammonia	Dried Blood
1	.....	.....	.....	.....	.....	.....	.....
2	1.19912	.83545	.88872	.89042	5.11190	1.00852	1.02768
3	.71927	.35700	.40040	.46368	7.88018	.37140	.39185
4	.22490	.08570	.09621	.14782	2.33056	.25401	.08547
5	.13651	.20253	.08983	.18265	.42241	.44622	.15746
6	.14105	.22416	.08109	.26775	.12400	2.15917	.19874
7	.19144	.30850	.10051	.51971	.12006	1.94687	.29190
8	.30333	.38364	.09843	.76440	.13075	1.80652	.65032
9	.35644	.53732	.12138	1.03635	.15700	1.91406	.76230
10	.29561	.50323	.12613	.89288	.14940	1.72121	.77920
11	.31053	.60375	.19569	.86908	.19387	1.11168	.76485
12	.28988	.52920	.11540	.70623	.19142	.70231	.55706
13	.18600	.52272	.13257	.58332	.17006	.53900	.51624
14	.27552	.45866	.12651	.46792	.18737	.37161	.65653
15	.27968	.47062	.15699	.39136	.18624	.33129	.57329
16	.26499	.44421	.11147	.33222	.13683	.24867	.44481
17	.23924	.34006	.12495	.32719	.13369	.17469	.31410
18	.21949	.24019	.08257	.19541	.08235	.12032	.18361
19	.22988	.24745	.08221	.18281	.09947	.11771	.14187
20	.18237	.18120	.07491	.16900	.12264	.11298	.12768
21	.13918	.16088	.07056	.15263	.08581	.12952	.13952
<b>TOTAL</b>	<b>6.18443</b>	<b>7.63647</b>	<b>3.27653</b>	<b>9.54283</b>	<b>18.01601</b>	<b>15.58876</b>	<b>8.76448</b>

That the soil used in these experiments contained a considerable quantity of nitric nitrogen was shown by the statement of analysis given on page 6. This nitrogen amounted to 2.36 grams for the soil in each tub, of which quantity nearly 38 per cent. was leached from the unfertilized soil (No. 7) in the first drainage. The high content of nitric nitrogen in the first two drainages from all the lysimeters, with the exception of No. 9, to which nitrate of soda was applied, can thus be largely attributed to the nitrates which were stored up in the soil prior to the starting of the tests.

The total nitric nitrogen washed into the drainage receiver in the case of lysimeter No. 7, the soil of which contained no added nitrogenous material, was 3.28 grams. Using this quantity as a basis and comparing the same with the total weight of nitric nitrogen found in the drainage waters from the other soils, it will be found that nitric nitrogen yielded by the different com-

pounds employed and which was leached from the respective tubs varied between 2.91 grams with tankage and 14.74 grams with nitrate of soda. To facilitate a comparison of the rapidity of nitrification in the several instances, the length of time during which the experiments were under way may be divided into periods as follows:

Period	Irrigations	Length of Period
1	1 to 4 inclusive.	Mar. 14 to April 4
2	5 to 8 inclusive.	Apr. 4 to May 31
3	9 to 12 inclusive.	May 31 to July 25
4	13 to 16 inclusive.	July 25 to Sept. 19
5	17 to 21 inclusive.	Sept. 19 to Nov. 21

The amounts of nitric nitrogen caught in the receivers during these periods are shown in the following tabulated statement:

Nitric Nitrogen in Drainage due to Nitrogenous Fertilizers added  
to Soil.  
Grams.

Period	5	6	8	9	10	11
	Tankage	Fish-scrap	Hoof-meal	Nitrate of Soda	Sulphate of Ammonia	Dried Blood
1	.75796	— .10718	.11659	13.93731	.24860	.11967
2	.40247	.74897	1.36465	.42736	.5.08802	.02856
3	.69386	1.61490	2.94594	.13309	4.89066	2.30481
4	.47865	1.36867	1.24728	.15296	.96303	1.66333
5	.57496	.73458	.59184	.08876	.22002	.47158

These figures were obtained by deducting the amounts of nitric nitrogen leached from the unfertilized soil during each period from the amounts contained in the drainage waters from the fertilized soils during corresponding periods. Expressing the weights of nitrogen given in the preceding table in percentages of the original amount applied to the soils, namely, 16.3 grams, the following results are obtained:

Nitric Nitrogen in Drainage for Different Periods.  
Percentage of Nitrogen added to Soil.

Period	5 Tank- age	6 Fish- scrap	8 Hoof- meal	9 Nitrate of Soda	10 Sulphate of Ammonia	11 Dried Blood
1	4.64	— .66	.72	85.50	1.53	.73
2	2.47	4.59	8.37	2.62	36.74	5.70
3	4.26	9.91	18.07	.82	30.00	14.14
4	2.94	8.40	7.65	.94	5.91	10.21
5	3.53	4.51	3.63	.54	1.40	2.89
Total	17.84	26.75	38.44	90.42	75.58	33.67

The total amounts of nitrogen recovered as nitrate varied between 90.42 per cent. in the case of nitrate of soda and 17.84 per cent. in the case of tankage during a period of practically eight months. While these figures are instructive and give one an idea of the relative rate and extent of nitrification in the several instances, they can be taken as only close approximations for two reasons:

1. It is a well-known fact that denitrification or the reduction of nitrates takes place in soils highly charged with water (preventing proper aeration) or containing readily oxidizable compounds.

2. At the conclusion of the last irrigation, the soils contained a quantity of nitric nitrogen which had not passed into the drainage receivers.

It is not known to what extent denitrification proceeded in the soils under consideration, although the belief is warranted that this action was not great, notwithstanding the high average moisture content, about 87 per cent. of saturation, maintained during the course of the investigations. Where nitrate of soda was applied, 85.5 per cent. of the added amount was recovered in three weeks' time from a soil holding an average amount of water corresponding to over 95 per cent. of that held at the saturation point. The last discharges of drainage water from tub No. 9, when compared with those from tub No. 7, the check lysimeter, indicate that very little of the nitric nitrogen derived from the nitrate of soda originally added was present in the soil water at the conclusion of the tests; it may be safely concluded, therefore,



that not more than 9 per cent. of the added nitrate was denitrified in this particular instance. In the case of those lysimeters containing organic fertilizers, conditions were more favorable for denitrification owing to the presence of readily oxidizable matters, and the reducing action was doubtless greater than in the cases where nitrate of soda and sulphate ammonia were added. Where tankage was employed, the organic matter of the soil (water-free) was increased by .42 per cent., and with dried blood the increase was .16 per cent., the fishscrap and hoofmeal giving gains in organic matter intermediate between these figures. The fact that the tankage, fishscrap, etc., were not incorporated throughout the soil mass in each tub, but were mixed with a fifty-pound layer of soil, would in all probability exert an influence favoring denitrification. However, the small extent to which the denitrifying action took place with nitrate of soda, would persuade us that the comparatively small amounts of nitric nitrogen which appeared in the drainings from tubs Nos. 5, 6, 8 and 11 were due chiefly to their inherent inability to yield nitric nitrogen at anything approaching the rate of sulphate of ammonia, under similar conditions, and also to the fact that a portion of the nitrogen in such organic materials is indefinitely inert.

On reviewing the data presented in the foregoing tables, a striking difference is manifested in the amounts of nitric nitrogen which were contained in the soils of the various lysimeters during the separate periods. While these amounts overlap to a certain extent owing to some of the nitric nitrogen formed in one period leaching out in the first drainages of a succeeding period, the results are sufficiently reliable to afford an insight into the behavior of the various substances in the supplying of assimilable nitrogen for the feeding of plants. During the first period, from March 14 to April 4, practically all of the nitrogen added in the form of nitrate of soda was available; the smallest quantity converted into nitrates during this time being that furnished by the fishscrap. The fact that somewhat less nitric nitrogen was leached from the soil containing fishscrap than was caught in the drainage receiver of the check experiment was doubtless due to a slight non-uniformity of the soil samples or to some small error in analysis. In the second period, from April 4 to May 31, the largest quantity of available nitrogen was contained in the "sulphate of ammonia tub" and the smallest amount in the "tankage tub." For the third period, between May 31 and July 25 tub No. 10, containing sulphate of ammonia, still holds first place with 30 per cent. of its

originally added nitrogen in the form of nitrate, and the "nitrate of soda tub" comes last with about 2.3 per cent. of nitric nitrogen, this latter figure being the sum of the amounts of nitrogen caught by the receivers between May 31 and the end of the tests, for the reason that the quantity passing off in the drainings of the fourth and fifth periods was necessarily present in the soil during the third period. The fourth period, between July 25 and Sept. 19, finds the tub containing dried blood in the lead with the "nitrate of soda tub" last. The last period, Sept. 19 to Nov. 21, gives tub No. 6, containing fishscrap, the ascendancy, and, as before, tub No. 9 with nitrate of soda contains the least nitric nitrogen. The following table gives the order in which the different materials were supplying nitric nitrogen during the progress of the investigations:

Order	1st Period March 14- April 4	2nd Period April 4- May 31	3rd Period May 31- July 25	4th Period July 25- Sept. 19	5th Period Sept. 19- Nov. 21
1	Nitrate of Soda	Sulph. of Ammonia	Sulph. of Ammonia	Dried Blood	Fishscrap
2	Tankage	Hoofmeal	Hoofmeal	Fishscrap	Hoofmeal
3	Sulph. of Ammonia	Dried Blood	Dried Blood	Hoofmeal	Tankage
4	Dried Blood	Nitrate of Soda	Fishscrap	Sulph. of Ammonia	Dried Blood
5	Hoofmeal	Fishscrap	Tankage	Tankage	Sulph. of Ammonia
6	Fishscrap	Tankage	Nitrate of Soda	Nitrate of Soda	Nitrate of Soda

Eight months after these various nitrogenous manures were added to the soils of the lysimeters, the soil waters in the different tubs contained varying amounts of nitric nitrogen derived from the same. In the case of lysimeter No. 9, in which 16.3 grams of nitrogen as nitrate of soda was placed, it is shown that, notwithstanding the large volume of irrigation water passed through the soil during the time occupied by the tests, there was still, after an eight months period, a certain small amount of nitrate left which was derived from the quantity originally added. While these results with respect to nitrate of soda amply con-

firm the statements made by this Experiment Station concerning the extreme liability of this material to waste when applied to our cane soils, under conditions which allow of copious drainage, it is a matter of some importance to know that the loss from denitrification does not assume serious proportions in the great majority of fields on irrigated plantations, containing, as they do, a small percentage of organic matter and where the growing cane and the exposure of the lands do not readily permit the maintenance of such a high average moisture content as that indicated in the soil of these lysimeter tests, notwithstanding the perfect drainage facilities of the latter. Under field conditions at the Experiment Station, the average moisture content of the soil, where 3 inches of irrigation water is applied weekly, is approximately 70% of saturation.

While a study of the figures yielded by the experiments under consideration is interesting and instructive, inasmuch as they indicate the relative rate of nitrification of various nitrogenous compounds under certain given conditions with respect to the content of moisture and organic matter of the soil in which the substances are placed, it is evident that the data cannot be indiscriminately applied to all of the varying plantation conditions.

On investigating the extent of denitrification in a sample of Pohakea soil very high in organic matter, Dr. E. C. Shorey found a given amount of nitrate to be acted upon very rapidly by denitrifying bacteria, the conditions under which his test was conducted being as follows: "One thousand grams of soil containing 15 parts per million of nitrogen as nitrate were placed in a glass percolator of such size that the soil was about 8 inches in depth, and after saturation with water was allowed to stand 24 hours. Three hundred cubic centimeters of water containing 1 gram of potassium nitrate was then added, the drainage caught, and the total nitrogen, nitrate, ammonia and nitrites determined in aliquot portions. This was repeated at intervals of 24 or 48 hours until 1.42 grams of nitrogen as potassium nitrate had been added. The soil was then washed until the drainage was free from nitrate, the drainage being analyzed as before." The figures gained from this test were:

	Grams
Total nitrogen added as nitrate .....	1.42
Total nitrogen recovered in drainage .....	.56
Difference .....	.86

The nitrogen caught in the drainage was divided as follows :

	Grams
Recovered as nitrate .....	0.268
Recovered as ammonia .....	.257
Recovered as nitrite .....	.008
Recovered in other forms .....	.027

These figures indicate a progressive reduction of nitrates to ammonia in the soil and probably, as inferred by Shorey, to a difficultly soluble organic form. The evolution of nitrogen gas from the soil was not apparent during the investigation, and a total nitrogen determination made at the conclusion of the test showed a gain in nitrogen corresponding closely with the difference between the nitrogen added and that contained in the drainage. While such a passing of soluble nitrogen into a comparatively inert form through the agency of micro-organisms constitutes a loss as far as the immediate efficiency of such nitrogenous fertilizing material is concerned, it is naturally less serious than the action produced by other denitrifying bacteria which reduce the nitrates to nitrogen gas with a resultant loss of nitrogen from the soil.

To note the effect of nitrate of soda, sulphate of ammonia and dried blood upon the lime of the soil used in the lysimeter tests described in the preceding pages of this bulletin, the amounts of this latter element carried away in the drainage waters from tubs Nos. 7, 9, 10 and 11 were carefully determined, with the following results:

Lime Contained in Drainage.  
Grams.

Irrigation No. of	7	9	10	11
	Check	Nitrate of Soda	Sulphate of Ammonia	Dried Blood
1	.....	.....	.....	.....
2	6.0517	11.0484	6.05115	6.3580
3	2.99585	9.99277	3.98652	2.97343
4	1.55658	3.10107	3.71574	1.18770
5	.76217	.94605	2.62856	.69239
5	.49484	.46046	2.67746	.47712
7	.41693	.38272	2.55937	.40650
8	.30000	.27456	2.29059	.53508
9	.30940	.28500	2.33906	.63600
10	.24612	.27272	1.77927	.60408
11	.23707	.31446	1.36762	.52806
12	.23026	.27346	1.00584	.46277
13	.24877	.23306	.86900	.45623
14	.23870	.34991	.71368	.56108
15	.35956	.48327	.76734	.55888
16	.27125	.20996	.66518	.47392
17	.27710	.20527	.55361	.33970
18	.22213	.11340	.40108	.24924
19	.24403	.15236	.40964	.25069
20	.25286	.17071	.37391	.25019
21	.30240	.16903	.44188	.27331
Total	16.01772	29.43864	35.59650	18.27437

While there was some little difference in the total quantities of drainage water from these lysimeters, following the application of the same amounts of irrigation water, the data yielded by the experiments with respect to the quantities of lime removed through the agency of nitrogenous fertilizers are sufficiently comparative for our purposes. The soil to which none of the substances under consideration was added lost 16.02 grams of lime. Where nitrate of soda was applied, 29.44 grams of lime were found in the drainage receiver, of which quantity 13.42 grams were due to the effect of the nitrate. The sulphate of ammonia

was responsible for a loss of lime from the soil of tub No. 10, amounting to 19.58 grams, and the dried blood occasioned a loss of 2.25 grams.

While these results confirm those of lysimeter tests reported in Bulletin No. 8 of this Division respecting the greater loss of lime from soils following applications of sulphate of ammonia as compared with nitrate of soda, per unit weight of nitrogen added, the data on this point with reference to dried blood show a non-conformity. Where water with 200 grains of salt per U. S. gallon was passed through a soil containing dried blood, the loss of lime was greater than where the soil contained nitrate of soda. These experiments with *fresh water* as shown above yielded results which are quite contrary to those previously reported with reference to salt water drainages, and further work along this line is necessary to elucidate this very interesting point. The fact that for each pound of nitrogen added to this particular soil 1.2 pounds of lime were rendered soluble where sulphate of ammonia was used, and 0.82 pound of lime where nitrate of soda was applied, shows that the idea which is prevalent in these islands to the effect that nitrate is the "lime robber," comparatively speaking, is unfounded. Similar results to these have been reached by the Rothamstead and other stations dealing with the composition of drainage waters.



## SECOND SERIES OF LYSIMETER TESTS.

These tests were conducted to note the effect on the Station soil of heavy dressings of burned lime, ground coral and gypsum with respect to the rate of nitrification, and the amounts of lime, potash, and phosphoric acid passing off in the drainage water following copious irrigations. All of the conditions of the experiments were the same as those described for the first series, except that to each of three quantities of soil, instead of adding nitrogenous materials, lime was applied in several different forms at the rate of 100 grams per 100 pounds of water-free soil. Tub No. 7, which constituted the check in the preceding experiments, also offered the basis for comparison in the second series, the tests having been started simultaneously. The nature and quantities of the materials used in these investigations were as follows:

No. of Lysimeter	Material Added to Soils	Quantity of Material Added to Soils
1	Burned Lime	167 grams
2	Ground Coral	378 grams
3	Gypsum	472 grams
4	Bonemeal	504 grams
7	Check	.....

Data on the water content of the soils during the progress of the experiments, the amounts of irrigation and drainage, and the quantities of nitric nitrogen, lime, and potash caught in the drainage receivers are presented in the following tables:

## Irrigation and Drainage.

No. of Irrigation	1		2		3	
	Irriga- tion Liters	Drainage Liters	Irriga- tion Liters	Drainage Liters	Irriga- tion Liters	Drainage Liters
1	20	.....	20	.....	20	.....
2	10	5.300	10	5.550	10	5.060
3	10	6.930	10	7.000	10	6.800
4	10	7.180	10	7.590	10	7.450
5	15	7.000	15	7.060	15	6.940
6	15	5.800	15	6.300	15	6.370
7	15	5.250	15	6.200	15	6.200
8	15	4.100	15	6.030	15	5.800
9	15	4.790	15	6.000	15	6.350
10	15	4.330	15	5.320	15	5.000
11	15	4.400	15	5.550	15	5.470
12	15	3.810	15	5.030	15	5.110
13	15	5.300	15	6.550	15	5.360
14	15	5.910	15	6.460	15	6.020
15	15	6.080	15	6.090	15	6.220
16	15	6.960	15	6.740	15	6.410
17	15	6.410	15	6.410	15	6.040
18	15	5.110	15	5.140	15	4.460
19	15	4.850	15	5.000	15	4.440
20	15	4.750	15	5.170	15	4.480
21	15	6.060	15	6.400	15	5.670
Total	305	110.32	305	121.59	305	115.65

Moisture of Soils Previous to Respective Irrigations, Showing  
Percentage of Saturation.

Irrigation No.	1	2	3	7
	Lime	Ground Coral	Gypsum	Check
1	34.68	34.68	34.68	34.68
2	85.71	86.47	84.98	85.68
3	90.66	90.87	90.26	91.34
4	91.42	92.68	92.25	92.18
5	75.67	72.82	75.49	75.39
6	72.01	73.66	73.75	74.51
7	70.34	73.24	73.24	75.42
8	66.85	72.72	72.02	73.39
9	68.95	72.62	73.70	75.06
10	67.54	70.57	69.59	72.21
11	67.76	71.26	71.02	72.75
12	65.97	69.69	69.92	70.96
13	70.50	74.31	70.68	73.91
14	72.36	74.03	72.70	75.12
15	72.87	72.90	73.30	76.03
16	75.54	74.88	73.88	75.67
17	73.87	73.88	72.75	75.06
18	69.92	70.02	67.95	69.66
19	69.13	69.59	67.89	70.26
20	68.83	70.10	68.00	70.75
21	72.81	73.85	71.63	73.85

Average Percentage of Saturation Between  
Respective Irrigations.

Intervals Between Irrigations, Nos.	1	2	3	7
	Lime	Ground Coral	Gypsum	Chalk
1 and 2	92.85	93.23	92.49	92.84
2 and 3	95.33	95.43	95.13	95.67
3 and 4	95.71	96.34	96.12	96.09
4 and 5	87.83	86.41	87.74	87.69
5 and 6	86.00	86.83	86.87	87.25
6 and 7	85.17	86.62	86.62	87.71
7 and 8	83.42	86.36	86.01	86.69
8 and 9	84.47	86.31	86.85	87.53
9 and 10	83.77	85.28	84.79	86.10
10 and 11	83.88	85.63	85.51	86.37
11 and 12	82.98	84.84	84.96	85.48
12 and 13	85.25	87.15	85.34	86.95
13 and 14	86.18	87.01	86.35	87.56
14 and 15	86.43	86.40	86.65	88.01
15 and 16	87.77	87.44	86.94	87.83
16 and 17	86.93	86.94	86.37	87.53
17 and 18	84.96	85.01	83.97	84.83
18 and 19	84.56	84.79	83.94	85.13
19 and 20	84.41	85.05	84.00	85.37
20 and 21	86.40	86.92	85.81	86.92
Average	86.71	87.49	87.12	87.97

## Nitric Nitrogen in Drainage Water.

Grams.

Drainage from Irrigation No.	1	2	3	7
	Lime	Ground Coral	Gypsum	Check
1	.....	.....	.....	.....
2	.89782	.97125	.77924	.88872
3	.46569	.49000	.37128	.40040
4	.08149	.11422	.10951	.09621
5	.10500	.08683	.07772	.08983
6	.08729	.08268	.06019	.08109
7	.10749	.11609	.08788	.10051
8	.08825	.10763	.08932	.09843
9	.12238	.12390	.10779	.12138
10	.11366	.12382	.08400	.12613
11	.12881	.13597	.10051	.19569
12	.09401	.13071	.08763	.11540
13	.11686	.12723	.07222	.13257
14	.11583	.13679	.08638	.12651
15	.08937	.14281	.10340	.15699
16	.11814	.14036	.10207	.11147
17	.10095	.12114	.08138	.12495
18	.08137	.09714	.05931	.08257
19	.07299	.08050	.06449	.08221
20	.07231	.09680	.05096	.07491
21	.07847	.10528	.08400	.07056
Total	3.13818	3.53115	2.65928	3.27653

## Potash in Drainage Water.

Grams.

Drainage from Irrigation No.	1	2	3	7
	Lime	Ground Coral	Gypsum	Check
1	.....	.....	.....	.....
2	1.17831	.77630	1.01599	.83332
3	.73002	.54048	.57780	.49242
4	.29808	.50210	.50368	.35531
5	.23492	.25910	.79116	.29229
6	.18284	.21602	.39174	.21030
7	.14564	.15997	.38910	.18459
8	.11294	.16902	.36766	.15277
9	.14426	.16703	.41792	.17677
10	.13209	.13881	.30506	.15887
11	.13614	.15773	.33851	.15097
12	.11049	.12490	.30040	.17366
13	.14240	.12421	.28569	.16164
14	.16194	.16774	.32321	.16571
15	.15422	.16776	.38794	.21064
16	.19848	.17259	.40974	.15854
17	.17906	.16632	.34742	.17446
18	.14523	.14010	.25416	.15095
19	.13572	.16320	.28166	.12025
20	.13947	.12662	.28137	.15081
21	.13255	.14899	.38471	.12759
Total	4.79480	4.58899	8.35492	4.60186

## Lime in Drainage Water.

Grams.

Drainage from Irrigation No.	1	2	3	7
	Lime	Ground Coral	Gypsum	Check
I	.....	.....	.....	.....
2	5.89890	6.02730	5.11060	6.05170
3	3.05613	3.09400	3.34560	2.99585
4	1.10572	1.37758	2.49947	1.55658
5	.47600	.53656	3.09588	.76217
6	.26100	.40162	1.98998	.49484
7	.22443	.32860	1.95610	.41693
8	.17117	.28190	1.81395	.30000
9	.22273	.26850	1.96215	.30940
10	.19809	.26866	1.50000	.24612
11	.23980	.23448	1.70664	.23707
12	.17430	.22509	1.50234	.23026
13	.20140	.30130	1.51554	.24877
14	.27747	.27132	1.61185	.23870
15	.31312	.29993	1.77736	.35956
16	.22622	.25443	1.90738	.27125
17	.26601	.25319	1.78935	.27710
18	.21462	.27113	1.34357	.22213
19	.22916	.24250	1.47963	.24403
20	.20543	.23394	1.48960	.25286
21	.26209	.31520	1.88527	.30240
Total	14.22379	15.48723	41.28226	16.01772

Considering first the quantities of nitric nitrogen in the drainage waters from the various tubs and comparing the figures yielded by lysimeters Nos. 1, 2, and 3 with the total nitric nitrogen in the drainings from the soil (No. 7) to which no lime compound was added, it will be noted that ground coral caused an increase of nitric nitrogen in the soil water and burned lime and gypsum caused a decrease.

In adding one gram of lime ( $\text{CaO}$ ) in the materials under consideration to one gram of dry matter in the soil, the rate per acre of the applications of the various substances would be:

Burned Lime .....	3.92 tons
Ground Coral .....	8.87 tons
Gypsum .....	11.08 tons

For each ton of lime contained in the materials there was an approximate gain or decrease in the amounts of nitric nitrogen produced (figured on the acre basis), as follows:

Material	Gain or Decrease in Nitric Nitrogen
Burned Lime	—1.69 lbs.
Ground Coral	+3.10 lbs.
Gypsum	—7.54 lbs.

The gain or decrease in nitric nitrogen for each ton of material applied (on the acre basis) is shown by the following figures:

Material	Gain or Decrease in Nitric Nitrogen
Burned Lime	—1.66 lbs.
Ground Coral	+1.35 lbs.
Gypsum	—2.61 lbs.

This difference between the effect of quicklime and that of ground coral or lime carbonate on nitrification in this soil is doubtless due to the difference in the soil reaction following the application of the respective forms of lime. The addition of an amount of caustic lime in the test corresponding to nearly four tons to the acre evidently created a degree of alkalinity which was prejudicial to the activities of the nitrifying organisms, while in the case



of ground coral no injurious conditions of this nature were created. On other types of soil, containing large quantities of organic matter and small amounts of lime such a retardation of nitrification following the application of similar quantities of caustic lime would not be expected and in the case of soils highly charged with organic matters and characterized by an acid reaction large quantities of burned lime have proved radically effective in accelerating the nitrifying action. It is a matter of common observation that satisfactory results from liming are frequently not observed in the case of some soils until one or two years have elapsed since the application was made and the lime has been entirely or almost entirely converted into the carbonate form.

The fact that sulphate of lime or gypsum exerted a depressive influence upon nitrification is of considerable interest, the decrease in the quantity of nitric nitrogen produced being equivalent to approximately 7.54 pounds per acre for each ton of lime in the form of gypsum added to the soil. The deleterious action of gypsum in this particular is, in the opinion of the writer, an indirect one, and was caused by the large amounts of potash rendered soluble through displacement of that element by the lime of the gypsum. It will be noted by reference to the table on page 25 that the application of 472 grains of gypsum to the soil of lysimeter No. 3 resulted in an increase of potash in the drainage water amounting to 3.75 grams, equivalent to 198 *pounds per acre*. That the presence of this large quantity of potash in the water of the soil during the progress of the experiments was largely, if not wholly, responsible for the retardation of nitrification seems a logical conclusion, insomuch as potassium salts, when added in considerable quantities to the soil, are known to create unfavorable conditions for the nitrifying organisms. In applying fertilizers to various plats under Lahaina cane at this Station, it has been found that the continuous use of sulphate of potash alone tends to decrease the yields rather than raise them and that the best results are gained when nitrogen in readily available forms is added along with the potassic manures, the yields in such instances being considerably greater than where nitrogen is used by itself. This point is well illustrated by the data obtained from an eight-year test, comprising two plant and two ratoon crops. For purposes of comparison, the time of the experiment may be divided into two periods, each period representing one plant crop with the succeeding ratoons from the same.

Material Applied. 100 Lbs. of Each Element per Acre	Percentage of Gain In Sugar. FIRST PERIOD	Percentage of Gain or Loss In Sugar. SECOND PERIOD
Potash .....	9.5	-11.3
Nitrogen .....	8.7	+36.0
Nitrogen and Potash	48.1	+44.8

The nitrogen was added in a mixture containing nitrate of soda, sulphate of ammonia, and dried blood. That both nitrogen and potash are present in the Station soil in quantities insufficient for maximum yields is apparent from these figures. For the first period potash applied alone caused a small increase in the yields of sugar, for the reason that, although it very probably exerted a retarding influence upon the production of nitrates, the quantity of available nitrogen was still sufficient to permit a greater growth when supplemented with the required potash. than was the case with the unfertilized cane. That a small gain also followed the application of nitrogen alone is not inconsistent when it is considered that the nitrogen so added had an indirect as well as a direct value, and that small supplies of potash were made available through the action of the nitrate in the fertilizer and the nitrates produced from the nitrification of the sulphate of ammonia and dried blood. During the second period the soil of the potash plat which had been greatly depleted of nitrogen by the growth and harvesting of two crops of cane, produced such a small supply of nitrates under normal conditions that any check to nitrification from the addition of potassium salts became a serious matter with a consequent decrease in yields amounting to over 11 per cent. That the gain in sugar for the nitrogen plat during the second period amounted to 36 per cent is not surprising when it is considered that this plat contained much more available nitrogen and from the indirect action of the latter larger supplies of available potash than the depleted unfertilized plat which had borne two successive crops of unmanured Lahaina cane.

It should not be inferred from these results showing the check to nitrification brought about by heavy dressings of gypsum, that gypsum is a compound to be avoided in the mixing of cane fertilizers. The superphosphates applied in our high grade manures contain a large percentage of gypsum, and this latter material

is also often used as a "filler" in making up Hawaiian fertilizers. Dr. E. W. Hilgard in discussing the value of gypsum from the standpoint of its influence upon nitrification states:\*

"Earthy and alkaline sulphates \* \* \* \* seem to "act favorably throughout, at least up to .5 per cent this is especially true of gypsum, which, according to Pichard, "accelerate the process (nitrification) more than any other 'substance known."

The quantity of gypsum added to the soil in the test under consideration was equivalent to practically .55 per cent of the weight of the soil. The small quantities of this material used in mixed fertilizers are undoubtedly of benefit.

The figures showing the amounts of potash caught in the drainage receivers of lysimeters Nos. 1 and 2 are given on page 25. Where burned lime was applied to the soil the extra potash brought into solution in the soil water amounted to 0.19 grams or, figured to an acre basis, 9 pounds. Ground coral gave a slight decrease in the potash content of the drainage water from tub No. 2 amounting 0 .013 grams or 0.61 pounds to the acre. This difference between the quantities of potash removed in the drainage from tubs Nos. 2 and 7 is so small that it may be considered well within the limits of analytical error in this particular instance, although other unpublished data gained from similar lysimeter experiments with the Station soil have given a larger reduction in soluble potash following the application of large quantities of ground coral.

The quantities of lime in the respective drainage waters show large differences. Where burned lime was applied to the soil, the amount contained in solution in the soil water was 1.79 grams less than when no lime was added, and in the case of ground coral the difference was 0.53 grams in favor of the check experiment. On the other hand, the lime in the drainage from tub No. 3 containing gypsum showed a gain of 25.26 grams over that caught in the drainage receiver of tub No. 7, to which no lime compound was added. Applying these results to an acre scale, it is found that where 3.92 tons of burned lime were applied to the soil, the drainage water showed 84 lbs. of lime less than where lime had not been added; in the case of ground coral, 8.87 tons of this material being applied, the drainage water contained

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\* Hilgard's "Soils", page 147.

about 25 lbs. less. Through the addition of 11.08 tons of gypsum to the soil the drainage water showed a gain amounting to 1185 lbs. of lime. The reduction in the quantities of lime contained in the soil water by the application of large quantities of lime in the caustic and carbonate forms is a point of considerable interest and one which requires further investigation before any definite conclusions may be reached as the underlying causes of this phenomenon.

The solubility of the phosphoric acid of the soils was affected by the different forms of lime added to the tubs in the several experiments, although the amounts of this element found in the drainage water were very small in each instance. The quantities of phosphoric acid determined in the drainages were as follows:

Tub No.	Material Added	Phos. Acid in Drainage. Grams.
1	Burned Lime	.37338
2	Ground Coral	.36297
3	Gypsum	.24580
4	.....	.46662

It is noteworthy that where gypsum was applied, the smallest quantity of phosphoric acid passed into the receivers, the largest quantity being present in the drainage from the check lysimeter. Lime carbonate as ground coral reduced the solubility of the phosphates to a somewhat greater extent than caustic lime.







DIVISION OF AGRICULTURE AND CHEMISTRY

BULLETIN NO. 20.

REPORT OF WORK  
OF THE  
**EXPERIMENT STATION**  
OF THE

HAWAIIAN SUGAR PLANTERS' ASSOCIATION —



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**A Theory of the Extraction**  
OF  
**Sugar from Massecuities**

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BY NOËL DEERR

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HONOLULU, T. H.  
1907



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**REPORT OF WORK  
OF THE  
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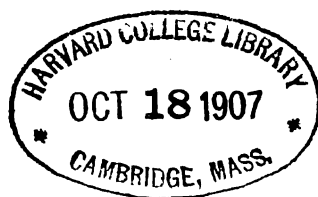
**A Theory of the Extraction  
OF  
Sugar from Masecutes**

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**BY NOËL DEERR**

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**HONOLULU, T. H.  
1907**



*Original*

### LETTER OF TRANSMITTAL.

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To the Experiment Station Committee of the Hawaiian Sugar  
Planters' Association, Honolulu, T. H.

Dear Sirs:—I, herewith, submit for publication as Bulletin  
No. 20 of the Division of Agriculture and Chemistry, an article  
entitled "A Theory of the Extraction of Sugar from Masse-  
cuites." This article has been prepared by Mr. Noël Deerr,  
Assistant Director of this Division.

Yours very respectfully,

C. F. ECKART,

Director, Division of Agriculture and Chemistry.

Honolulu, Hawaii, Aug. 20th, 1907.



# A THEORY OF THE EXTRACTION OF SUGAR FROM MASSECUTES.

By Noël Deerr.

The object of this bulletin is to collect into an accessible form the data requisite for a systematic scheme of sugar boiling and to establish some simple algebraical formulae connecting purity of massecuite and concentration to which it should be boiled to obtain the best results. Incidentally the bearing of these results on the process known as "Crystallization in Motion" and an apparatus known as the "Brasmoscope" are discussed.

At the risk of repeating what is fully known to every one connected with the sugar industry, some fundamental definitions are explained.

*Solubility.* The solubility of a solid in a liquid is a definite constant at any particular temperature, and is independent of any mechanical treatment (stirring or crystallization in motion) that the solution receives. In the appendix is given a table of the solubility of sugar in water at different temperatures.

The solubility of sugar in water is affected by the simultaneous presence of other bodies. In general, the combined effect of the bodies present in cane products is to *decrease* the solubility of sugar and in what may be termed Geerlig's Theory of molasses a definite relation between the relative amounts of organic potassium salts (as indicated by the alkalinity of the soluble ash) and glucose, and the solubility of sugar in exhausted molasses is established for Java molasses; this relation was not found by Mr. S. S. Peck to hold in the case of Hawaiian molasses.

It is certain, however, that certain bodies, of which organic potassium salts are examples are melassigenic, i. e., they increase the solubility of sugar in water. There is also reason to believe that in a sense the solubility of sugar in very impure solution is affected by the viscosity, i. e., if water be continually removed from impure sugar solutions the massecuite

eventually becomes so viscous that the sugar molecules have not sufficient freedom of movement to deposit on crystals already formed and (so to speak) remain in solution; actually the sugar is probably present in the solid state but in the form of microscopic or ultra-microscopic crystals.

*A saturated solution* is one where the dissolving medium (water for example) can dissolve no more of the solid, and consequently if the dissolving medium (water) be removed by evaporation, crystals of the dissolved body (sugar) separate.

*A Supersaturated Solution* is one where (temporarily) more solid is held in solution than is the case in the final position of equilibrium between solvent and dissolved solid. Such a position can be obtained by the gradual removal of water from a solution of sugar in water; in the change of a material from the dissolved to the solid state a certain resistance has to be overcome, and the change is not instantaneous; from a solution at or near the point of saturation water can be removed faster than the dissolved solid can change its state of aggregation and a state known as supersaturation results. Such a process actually happens in the pan; at graining a supersaturated solution is formed in which suddenly a crop of minute crystals appear. With pure solutions which are not very viscous the supersaturation is very low but as the boiling progresses and more and more sugar is removed from solution a more viscous mother liquor results; the resistance towards crystallization increases and the mother liquor becomes more and more supersaturated; on striking out the contents of the pan *eventually* all the sugar contained in supersaturated solution separates but in general unless the mass is kept stirred the crystals separate out as fine grain in a form not capable of recovery; the craft skill of the sugar maker should be directed towards maintaining the supersaturation in the mother liquor as low as possible, so that as much of the crystallization as possible is done in the pan; if a too high degree of supersaturation be allowed to occur in the pan there is danger of a sudden deposition of crystals in the form of fine or "false" grain; a rapid and complete circulation in the pan whereby crystals already formed are brought frequently into contact with the mother liquor is the cause which, as much as anything, goes to prevent a too high supersaturation.

All low grade strikes when boiled string proof, form supersaturated solutions on cooling from which the sugar separates with extreme slowness, in some cases weeks being taken before grain appears; if such a strike be watched as it cools it will be found that when it reaches the temperature of the air it is extremely viscid and remains so for some time; it is now in a state of supersaturation; suddenly the viscosity becomes much less, the mother liquor becomes liquid and more free, and grain is found to be abundantly present; this change from a viscous supersaturated solution to a free saturated solution and suspended solid often takes place with great suddenness.

*Boiling point.* All liquids are constantly giving off vapor from their surface and when the pressure of the vapor equals that of the surrounding atmosphere the liquid boils; as the pressure of the surrounding atmosphere increases so does the boiling point of the liquid, and conversely with a fall of pressure there is a corresponding fall in the boiling point; when water or other liquid boils under a pressure less than that normally due to the atmosphere it is said to boil under reduced pressure or less correctly "in vacuo." It is customary to express the pressure under which sugar solutions are boiled in "inches of vacuum." The normal pressure of the atmosphere will support a column of mercury 29.92 inches high; an absolute vacuum would then be expressed as 29.92 inches, and a vacuum of 25 inches will mean that the excess pressure of the atmosphere over the pressure in the vessel, in which there is a vacuum of 25 inches, is  $29.92 - 25 = 4.92$  inches. This method of expressing pressure less than one atmosphere is not altogether convenient and for many reasons it would be better to speak of a pan being boiled under a pressure of 5 inches absolute, rather than as under a vacuum of 25 inches. At the end of this bulletin is given a table connecting the temperature and pressure at which water boils, for pressures from 1 inch to 6 inches of mercury or roughly for vacua from 24 inches to 29 inches.

*Effect of dissolved solids on the boiling point.* The boiling point is increased by the presence of dissolved solids and the following important relation connects boiling point, amount of dissolved solid and pressure under which ebullition occurs.



"The elevation of the boiling point due to the dissolved solids is independent of the pressure under which ebullition occurs." For example, under a pressure of one atmosphere water boils at 212 deg. F. and a 75% solution of sugar at 225.2 deg. F. The elevation in the boiling point is then 13.2 deg. F.; under a pressure of 4 inches of mercury (25.9 inches of vacuum) water boils at 125.6 deg. F.; a 75% solution of sugar under the same pressure will then boil at  $125.6 + 13.2 = 137.8$  deg. F. The temperatures at which sugar solutions of different concentrations boil under atmospheric pressure have been determined (see table at end); if then the temperature of a boiling sugar solution be known, and also the pressure under which ebullition occurs, then from the elevation of the boiling point over and above the boiling point of water under the same pressure, the amount of sugar in the boiling mass can be at once found. For example, under a pressure of 4 inches of mercury a sugar solution boils at 159.4 deg. F.; water under this pressure boils at 125.6 deg. F.; the elevation in the boiling point then is 29.8 deg. F.; reference to the table of elevation of boiling points of sugar solutions gives the percentage of sugar as 86.25%.

This relation is the basis of an instrument known as a Brasmoscope or Brixometer.

*The Brasmoscope.* The Brasmoscope was introduced into the beet sugar industry by Curin in 1898 and its form has been modified and its use extended by Claassen.

It consists merely of an accurate thermometer (the bulb of which is immersed in the boiling mass in the pan and placed so as not to be affected by local causes such as the proximity of a steam coil) and an accurate barometer pressure gauge, the ordinary aneroid gauges not being of sufficient accuracy.

The form of barometer gauge usually found is a syphon barometer, Fig. 1; this consists of a U tube closed at the end A and open at the end B; the tube is filled with mercury and when held in a vertical position the difference of level between the mercury in the two limbs will give the pressure of the atmosphere in inches of mercury; this U tube is fixed on a board carrying a scale and is adjusted so that the level of mercury in the long limb is at the zero mark when under atmos-

pheric pressure; if the open end be now attached to a vessel in which there is a reduced pressure, the mercury in the long limb will fall until the difference in level is that due to the

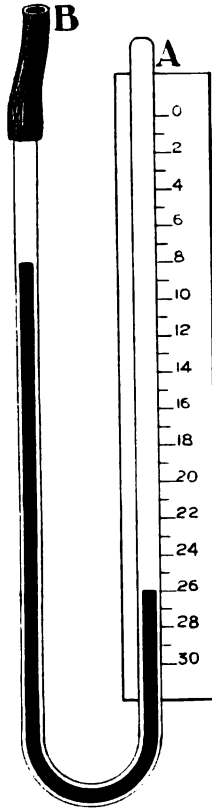


FIG. 1.

pressure in the vessel connected to the short limb; the scale is so graduated as to give directly inches of vacuum in the vessel to which the short limb is attached. This instrument is not too convenient as the gauge has always to be set at the zero mark and as a fall of pressure of, say, 1 inch in the vessel where the pressure is being measured only, causes the level of the mercury in the long limb to fall half an inch, the level of the mercury in the short limb at the same time rising half an inch. The writer has devised the pressure gauge described below, Fig. 2.

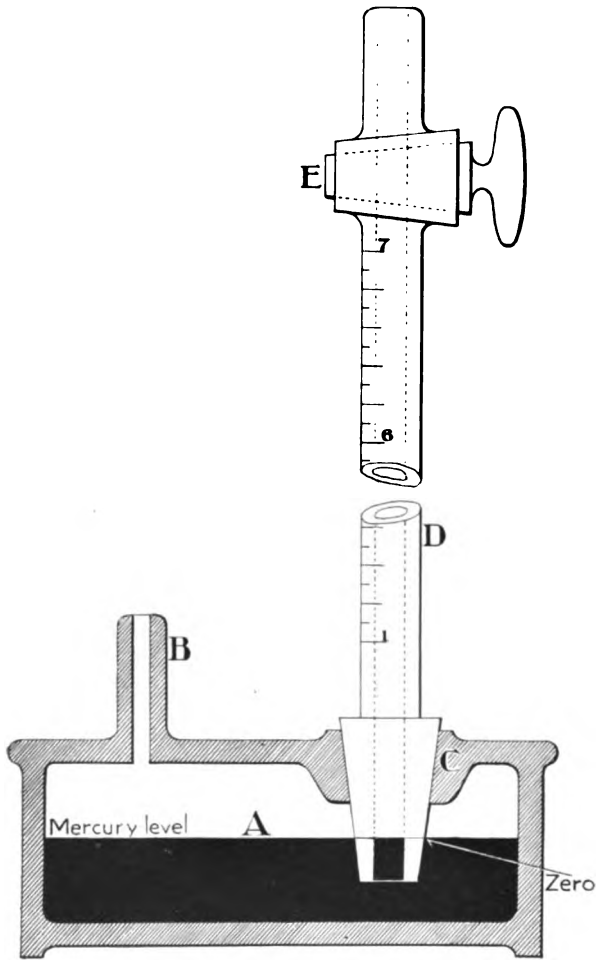


FIG. 2.

A is a shallow receptacle of thick glass partly filled with mercury; on the upper side at B is a tubulure to be connected to the vapor space of the pan by stout rubber tubing; at C is the neck of the receptacle into which fits tightly the barometer tubing D, graduated in tenths of an inch; the receptacle A being filled with mercury the graduated barometer tubing is then inserted in the neck of the flask and mercury is sucked up above the level of the stop cock at E which is then closed; the

mercury in A is then adjusted until its level is coincident with the zero mark on D; if then connection be made to the vapor space of a vacuum apparatus by way of B, the height of the column of mercury will directly measure the pressure in the pan.

After the pressure in the pan and the temperature of the boiling mass have been determined by reference to the tables, the elevation of the boiling point is found, and from this the apparent percentage of sugar in the boiling mass is determined.

Instead of using tables, Claassen has devised a mechanical scale for determining the apparent percentage of sugar. In Fig. 3, A, B and C are three scales; A and C are fixed and B is a sliding scale; A is the vacuum scale and C is the temperature scale; C is graduated in equal divisions corresponding to the divisions of a thermometer; on A, opposite to the temperature divisions on C, are marked the corresponding pressures or vacua at which water boils. The sliding scale B is graduated so as to connect the elevation of the boiling point with the amount of sugar present, on the same basis as the divisions in the scale C. A determination is actually made as under (see Fig. 3).

The vacuum in the pan is 28.0 inches and the temperature is 140 deg. F. The zero on the scale B is placed opposite 28.0 on the scale A; the division on the scale C corresponding to a temperature of 140.0 deg. F. is then noted, and opposite this on the scale B is the division 89.9, i. e., the boiling mass contains apparently 89.9% of sugar.

It may at once be stated that it is only bodies in solution that affect the boiling point, and that sugar that has crystallized out has no effect at all; it is only then, with masses boiled string-proof that the apparent sugar percentage of the whole mass is given; in other cases it is the apparent sugar percentage of the mother liquor. The scales in the bramoscope are calculated on a sugar basis, and give only the apparent percentage of total solids expressed as sugar, exactly as the Brix spindle gives also apparent total solids; actually the non-sugar causes weight for weight a greater elevation of the boiling point than does the sugar, so that the bras-

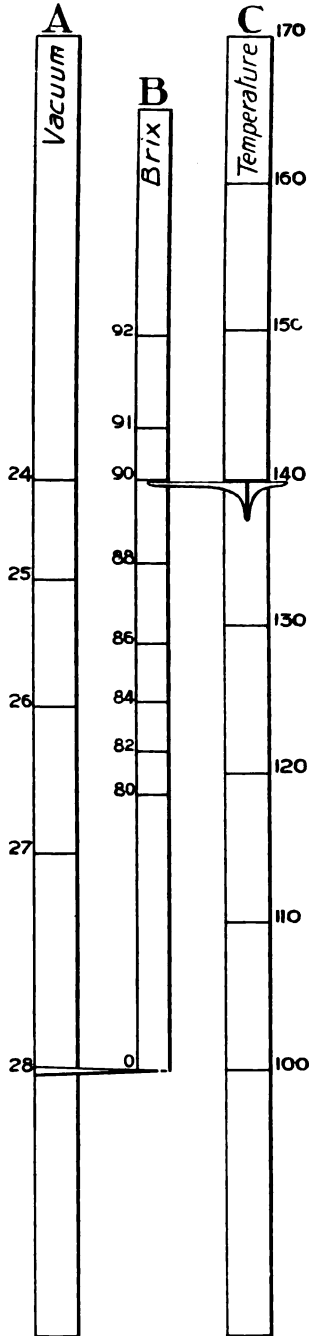


FIG. 3.

moscope indication will always be higher than the true total solids, and this will be more pronounced the impurer the mass being tested; the error in determining total solids with the Brix spindle also lies in the same direction.

*Application of the Brasmoscope.* The simplest instance of the use of the brasmoscope lies in its application to low products boiled string-proof; here no sugar separates in the pan as crystals, and the indications of the instrument will now refer to the Brix of the whole mass in the pan. Suppose it has been found by experience that a mass of 50 apparent purity gives the best results when boiled to an apparent Brix, as indicated by the brasmoscope, of 90; when this factor has once been determined it is an easy matter to boil all subsequent strikes of this purity to the same elevation of the boiling point, and this can, I believe, be done more exactly with the aid of graduated instruments than by the sense of touch of the most experienced sugar maker; the illustration given above demands, of course, that the nature of the non-sugar does not vary and, for one particular factory, I do not think that this assumption is too far from the truth.

Now in actual work the purity of the masses boiled will vary, and to extend the application of the brasmoscope it is necessary to solve the following problem:

"To find the connection between the Brix of a massecuite and the purity of the mother liquor or molasses, the solubility of sugar in the mother liquor being known."

Let  $x$  = Brix of the massecuite.

$s$  = solubility of sugar in the mother liquor or molasses.

$p$  = purity of the massecuite.

$m$  = purity of the molasses.

Then  $(1-x)$  = water in the massecuite.

$s (1-x)$  = sugar in solution, i. e., in the molasses.

$x (1-p)$  = total non-sugar or impurities.

(For convenience of calculation these purities are referred to unity instead of to 100 as is usual.)

Then

$$m = \frac{s (1-x)}{s (1-x) + (1-p) x}$$

and

$$x = \frac{s - ms}{s + m - ms - mp}$$

Now, according to Mr. S. S. Peck's analyses of Hawaiian waste molasses, on an average one part of water dissolves 1.78 parts of sugar and the average true purity of the molasses is 45.8. I have then calculated in Table I values of  $x$  for purities of the massecuite ( $p$ ) 46—95; when to  $s$  and  $m$  are given the values 1.8 and 46; this table gives on the data taken the degree Brix to which a massecuite must be concentrated, so that after complete crystallization the purity of the mother liquor or molasses is 46. Now from the values in the table it is seen that a massecuite of 50 purity will give molasses of 46 purity if concentrated to 80.86 Brix; actually suppose it is found that best results are obtained when the apparent Brix as shown by the brasmoscope is 86.5; it is now desired to find from the formula or table what should be the Brix as indicated by the brasmoscope when the purity of the massecuite is 55.

From the formula or table it follows that a massecuite of 50 purity concentrated to 80.86 Brix will give molasses of the same purity as one of 55 when concentrated to 82.44 Brix. The ratio between these two Brix is  $82.44 \div 80.86 = 1.0195$ . Hence the required Brix as indicated by the brasmoscope is  $86.5 \times 1.0195 = 88.19$ , i. e., if a massecuite of 50 purity gives molasses of 46 purity when concentrated to 86.5 Brix as indicated by the brasmoscope, a massecuite of 55 purity will give molasses of the same purity when concentrated to 88.19 as indicated by the brasmoscope.

Now, according to the equation, it is possible by boiling to a sufficient concentration to obtain in one process exhausted molasses; thus a syrup of 90 purity if boiled to a concentration of 95.48 Brix would, on the data on which Table I was constructed, give molasses of 46 purity; now from actual experience it is known that with the process commonly followed in these islands that four operations are necessary in general to obtain this end; there is no real disagreement between theory and practice but the causes of this are:

1. It is impossible to practically boil any massecuite to so high a concentration as 95.48; a massecuite so highly concentrated would have no circulation, it would bank up and burn on the coils and it would be a matter of difficulty to remove it from the pans and to manipulate it afterwards.

2. A very supersaturated solution of sugar would be formed in the final stages, from which, under the ordinary process of cooling at rest, sugar would separate with extreme slowness and in a form not suited to be recovered in the centrifugals.

Actually in practice it is known that the higher the purity of the massecuite the higher is the purity of the mother liquor or molasses; this is a natural sequence of the equation and in Table II, I have calculated out values of the purity of the mother liquor or molasses when the purity of the massecuite varies from 75 to 95 and the Brix of the massecuite is constant at 90. This table then connects the purity of the molasses with the purity of the massecuite from which they are derived, provided all the massecuites are boiled to the same degree Brix; actually, however, the higher the purity the higher is the concentration to which the massecuite is boiled.

The amount of sugar then that can be extracted as crystals from a massecuite depends on the degree Brix to which the massecuite can be boiled, or, conversely, to the least possible amount of water which can be left in the massecuite capable of retaining in solution the non-sugar, and it is immaterial, so far as regards the amount of sugar that crystallizes, whether the concentration is done in one or in more operations. This is best shown by a worked out example.

Let there be a syrup of 80 purity, let it be concentrated to a Brix of 90 and let the solubility of sugar in the mother liquor be 2, i. e., for every one part of water in the mother liquor let two parts of sugar be dissolved.

Then the massecuite is of composition

Water . . . . .	10
Sugar in solution . . . . .	20
Sugar as crystals . . . . .	52
Non-sugar . . . . .	18

---

100



Now let the 52 parts sugar as crystals be removed leaving 48 parts of first molasses of percentage composition

Water . . . . .	20.83	
Sugar . . . . .	41.66	
Non-sugar . . . . .	37.50	100
<hr/>		
Brix . . . . .	79.17	
Purity . . . . .	52.63	

and the sugar removed percent on that originally present is

$$\frac{100 \times 52}{72} = 72.22\%$$

leaving 27.78% in the molasses.

Now let these molasses be concentrated to a second masse-cuite at 90 Brix and let one part of water hold in solution two parts of sugar.

Then the percentage composition of the second masse-cuite is

Water . . . . .	10
Sugar in solution . . . . .	20
Sugar in crystals . . . . .	27.367
Non-sugar . . . . .	42.633
<hr/>	
100.00	

Now let 27.367 sugar in crystals be removed. Then per 100 sugar originally present there are removed

$$\frac{27.367}{47.367} \times 27.78 = 16.07\%$$

and the total amount of sugar removed in the two operations per 100 sugar originally present is  $72.22 + 16.07 = 88.29$ .

Now to find to what Brix the masse-cuite must be boiled in one operation so as to leave the same absolute amount of water in the masse-cuite, we can proceed as follows: In the second masse-cuite above the non-sugar is 4.2633 times the water and the purity of the original syrup being 80, the sugar in the original masse-cuite is four times as much as the non-sugar. Let  $x$  be the water percentage in the masse-cuite

boiled in one operation so that the absolute amount of water left is the same as that in the two operations above.

Then

$$x + 4.263x + 17.0532x = 100$$

$$x = 4.482$$

The composition of the massecuite boiled to this water content in one operation will be

Water . . . . .	4.482
Sugar in solution . . . . .	8.964
Sugar in crystals . . . . .	67.450
Non-sugar . . . . .	19.104

and if the 67.450 sugar in crystals be removed, the amount of sugar extracted per 100 sugar in the massecuite is

$$\frac{67.450}{76.414} \times 100 = 88.29\%$$

the same percentage as was obtained before in two operations.

From what has been already said it follows, that if a massecuite be boiled to a certain preascertained concentration depending on the purity and be allowed to cool, that eventually all the sugar capable of recovery will crystallize out; it does *not* follow, however, that all this sugar will crystallize out in a form capable of collection in the centrifugals or within a reasonable time; in the first place, owing to lack of contact of crystals already formed with any but a small portion of the mother liquor, sugar that crystallizes on cooling will form new fine crystals incapable of recovery in the centrifugals; in the second place, it is known how long it takes low masses to crystallize; the mother liquor of a first massecuite boiled to such a pitch that all the sugar capable of recovery will crystallize is in exactly the same condition as a low grade massecuite, and although in the case of a first massecuite crystallization will be more rapid owing to the presence of crystals already formed, yet a very considerable time will be taken for a complete separation of the sugar from the supersaturated mother liquor; if, however, the massecuite be kept in motion so that the layer or mother liquor in contact with crystals is being

constantly renewed deposition will take place much more readily and the sugar separating will deposit on the crystals already formed; this was the original object of the process known as crystallization in motion.

*Crystallization in motion* originally was applied to first products only; a massecuite was boiled in the usual way to the usual pitch and allowed to cool in motion; this process by allowing sugar held in solution due to high temperature and in supersaturated solution to deposit on crystals already formed gave an increased rendement in first product but in no wise could it obtain a complete desugarization of a pure massecuite unless the concentration was carried to the degree indicated by the formula

$$\frac{s-ms}{s+m-ms-mp}$$

and it has already been noted that so high a concentration is for mechanical reasons impossible. Following on this came the idea of working with masses of purity so reduced by the addition of molasses that on concentration to that water content where all the sugar capable of recovery crystallized, the massecuites were capable of ready manipulation and after cooling in motion on curing gave "first sugar and molasses," i. e., a complete commercial rendement without the interposition of low grade sugars.

A complete crystallization in motion or first-sugar and molasses process may then be defined as "A scheme in which the purity of massecuites are reduced to such a point that they are capable of practical manipulation when concentrated to that point when the water left is only just sufficient to hold in solution the non-sugar, combined with the cooling of the massecuites in motion whereby the deposit of sugar from supersaturated solution is accelerated and takes place on crystals already formed."

The technique of the various processes devised and used to this end may be summarized:

1. A massecuite is boiled from syrup alone and concentrated as far as possible; unexhausted molasses from a previous operation which have been diluted and heated so as to

dissolve any fine grain are then taken into the pan, the whole mixed massecuite concentrated to the proper point struck out and cooled in motion.

2. The process is conducted as above save that exhausted molasses are introduced; in this scheme the exhausted molasses should leave the centrifugals on curing at the same purity as that at which they entered the pan; they do not aid in the exhaustion of the syrup massecuite but only act mechanically as a medium in which the crystals swim.

3. The mixture of syrup and molasses is made without the pan, the formation of grain being obtained from syrup alone. As the sugar deposits the purity of the mother liquor decreases and it is the object of the scheme to avoid increasing from time to time the purity of the mother liquor by charging in pure syrup and to regulate the proportions of syrup and molasses charged in as the purity of the mother liquor falls.

4. The Java process which is now used in several factories in these islands and consists essentially of two strikes; the first of fairly high purity, which is cooled in motion for about 12 hours, and the second at a purity of about 60 which is cooled in motion for from 48 to 72 hours and from which exhausted molasses are obtained.

5. The Bock process in which a strike was boiled from syrup alone and run into crystallizers; about one-third of this strike was left in the crystallizer and on to this was struck a strike boiled from molasses obtained from a previous operation and the whole then cooled in motion.

6. A strike of molasses is boiled string proof and to the concentration required to yield exhausted molasses; into the pan immediately before the completion of the boiling is taken a quantity of sugar which is thoroughly mixed with the contents of the pan, after which the whole is struck out and cooled in motion; the amount of sugar crystals taken into the pan as "priming" is from 25% to 30% of the massecuite.

Whichever one of these schemes be used it is apparent that they all depend for their success upon the control of the water content of the massecuite.

*Application of the Brasmoscope to Masseccutes Boiled to Grain.*  
The application of the brasmoscope readings to control the

water content of massecuites boiled to grain is complicated in that the instrument does not give the Brix of the massecuite as a whole but of that of the mother liquor; what is required to be known may be expressed "What shall be the Brix of the mother liquor in the pan at the moment of observation so that on cooling exhausted molasses result," and algebraically the problem can be solved thus:

Let the solubility of sugar in molasses at a low temperature be  $s$  and let it be  $s'$  at a more elevated temperature; it is required to find what must be the Brix when the solubility is  $s'$  so that the purity is  $m$  when the solubility is  $s$ . Let  $x$  be the Brix of the molasses when the solubility of sugars is  $s$ .

Then

$$\begin{aligned} 1-x &= \text{water} \\ s(1-x) &= \text{sugar} \end{aligned}$$

and

$$m = \frac{s(1-x)}{x}$$

whence

$$x = \frac{s}{s+m} \quad (1)$$

Now let the solubility of sugar change to  $s'$  all other factors remaining the same.

The absolute amount of sugar in solution now is  $s'(1-x)$ , the water and non-sugar remaining the same.

If the Brix be now denoted by  $x'$ ,

$$x' = \frac{s'(1-x) + \{x-s(1-x)\}}{s'(1-x) + \{x-s(1-x)\} + 1-x}$$

For  $s$  put  $s+d$ ,  $d$  being the difference in the solubility of sugar at the two temperatures.

Then

$$x' = \frac{d+x-dx}{1+d-dx}$$

But  $x$  has already been shown to be equal to

$$\frac{s}{m+s}$$

Making the substitution

$$x' = \frac{d + \frac{s}{m+s} - \frac{ds}{m+s}}{r+d - \frac{ds}{m+s}} = \frac{s-dm}{s+m-dm} \quad (2)$$

As a numerical example let the solubility of sugar be 1.8 and let molasses of 46 purity be required; the Brix of these molasses will be from equation (1)

$$\frac{100 \times 1.8}{1.8 + .46} = 79.64$$

Now let the solubility of sugar become 2.5 so that  $d$  is .7. The Brix of the molasses now is from equation (2)

$$100 \times \frac{2.5 - .7 \times .46}{2.5 + .46 - .7 \times .46} = 82.57$$

Unfortunately the solubility of sugar in the hot mother liquor ( $s'$  in the equation established above) in the pan can not be exactly known; it is affected by the temperature prevailing, by the presence of non-sugar and by the degree of supersaturation; now at the temperature  $40^\circ$  C at which it is customary to cure massecuites boiled to grain and cooled in motion the solubility of sugar in water is 2.38 and at the temperature  $70^\circ$  C which is approximately that of the massecuite in the pan the solubility is 3.20; the ratio of these is 1.34; previously I took the solubility of sugar in Hawaiian exhausted molasses as 1.8, that is to say, at the normal temperature here say  $27^\circ$  C; between  $27^\circ$  C and  $40^\circ$  C the solubility of sugar in water increases in the ratio 1.11 and hence at  $40^\circ$  C, I take the solubility of sugar in Hawaiian molasses as  $1.11 \times 1.8 = 1.998$  and at  $70^\circ$  C  $1.998 \times 1.34 = 2.68$ ; cutting off the decimals then the values of  $s$  and  $s'$  in the equation established above will be taken as 2.0 and 2.7.

Now owing to supersaturation the lowest solubility possible in the pan at the temperature of  $70^\circ$  C will be 2.7 and it may be considerably higher; I have then calculated out values of the equation

$$\text{Brix} = \frac{s - md}{s + m - md}$$

for values of  $s = 2.0$ ,  $d = 0$  to  $1.3$  ( $s' = 2.7$  to  $4.0$ ) and  $m = 38$  to  $50$ . These are given in Table III below; in the vertical column on the left hand side are entered the solubilities of sugar in the molasses in the pan; in the horizontal caption are entered the values of  $m$  from  $38-50$ ; the figure at the intersection of a vertical and horizontal line gives the degree Brix of the molasses in the pan so that when the solubility of sugar becomes  $2.0$  molasses of the purity in the column selected will result.

*Example.* The solubility of sugar at the moment of observation is  $3.0$  and it is desired to obtain molasses of  $40$  purity when the solubility is  $2.0$ ; at the intersection of the line  $3.0$  and  $40$  is the figure  $84.82$ , i. e., the Brix of the molasses in the pan must be  $84.82$

As I pointed out in dealing with the application of the brasmoscope to mass cuites boiled string proof it is impossible to state beforehand what the indication of the brasmoscope should be, and the brasmoscope indications must be systematically compared with the actually recorded results in the factory; when once the brasmoscope indications corresponding to molasses of a satisfactory low purity are obtained then it should be possible to reproduce those conditions more exactly than can be done by the senses of sight and touch.

The process of exhausting rapidly low grade massecuites mentioned above as No. 6 would appear to be a scheme to lend itself readily to a very complete control as it would only be necessary to determine the proper concentration of the low grade massecuite before taking in the sugar used as "priming," as had already been indicated when dealing with the application of the brasmoscope to massecuites boiled string proof; actually I have never seen this scheme worked but I believe it is in considerable vogue in beet sugar factories.

Below I call attention to one or two points of interest not previously mentioned:

1. *Size of crystals.* The rate at which sugar deposits from supersaturated solution is intimately connected with the area of the sides of the crystals which in a given time come in contact with the mother liquor; the smaller the grain the larger is the area of the sides of the crystals and hence desugarization of a supersaturated mother liquor will take place more rapidly with a small grain sugar than with a large one.

2. *Rate of cooling.* As a general rule when a grained massecuite is discharged the supersaturation is relatively high; if such a massecuite be quickly cooled the deposit of sugar takes place with such suddenness that the sugar now separating from solution does not deposit on the crystals already present but goes to form new crystals; in these islands, I believe, the crystallizing tanks are plain and are not provided with jackets so that means do not exist for controlling the rate at which the massecuite cools; in beet sugar factories, I believe, great attention is paid to this point and it is general to construct crystallizing tanks with jackets into which steam or water may be admitted; the temperature of the massecuite is allowed to fall very slowly at first until (largely aided by the movement of the massecuite) the supersaturation is decreased; after which the rate of cooling is allowed to become more rapid. The rate at which a body cools is, with certain limitations, proportional to the excess temperature and with unjacketed tanks the rate of cooling will be greatest in the earlier stages—precisely the reverse of what is demanded by the above argument.

3. *Remelting low sugars.* When low sugars are remelted the purity of the massecuite is increased and it has already been shown that an increased purity in the massecuite implies an increased purity in the molasses; on these grounds then remelting low sugars is not a process to be recommended and it should rather be the object of the sugar maker to strive to suppress low products altogether rather than to eliminate them by the process of remelting.



## SUMMARY.

1. The amount of sugar crystallized depends on the absolute amount of water left in the massecuite.

2. It is immaterial in so far as regards the amount of sugar that crystallizes if the total amount of water evaporated from a syrup be removed in one or in more operations.

3. A certain amount of water has to be left in a massecuite to enable it to be manipulated; with massecuites of high purity to obtain in one boiling all the sugar, that can crystallize, the concentration has to be so high that manipulation becomes impossible.

4. By lowering the purity of massecuites the concentration corresponding to the point at which exhausted molasses result may be obtained the massecuites at the same time being sufficiently fluid to handle.

5. By allowing these massecuites of reduced purity to cool in motion the time taken for sugar to separate from supersaturated solution is diminished and under careful control of the rate of cooling the sugar deposits on the crystals already formed.

6. Systematic observations of the elevation of the boiling point of the mass in the pan form a valuable guide to the operator.

Finally I wish to emphasize that the brasmoscope is not in any way intended to supersede the craft skill of the experienced sugar maker; it is intended to be used rather as an adjunct and a guide and to substitute a definite scientific relation for the varying senses of sight and touch.

TABLE I.

Values of the expression  $100 \times \frac{s-ms}{s+m-ms-mp}$  for values of  
 $s$  1.8, and  $m$  .46, and of  $p$  .46 to .95.

p		p		p	
.46	79.65	.63	85.09	.80	91.35
.47	79.95	.64	85.44	.81	91.75
.48	80.25	.65	85.79	.82	92.15
.49	80.56	.66	86.14	.83	92.55
.50	80.86	.67	86.49	.84	92.96
.51	81.17	.68	86.85	.85	93.37
.52	81.49	.69	87.21	.86	93.79
.53	81.80	.70	87.57	.87	94.20
.54	82.12	.71	87.93	.88	94.62
.55	82.44	.72	88.30	.89	95.05
.56	82.76	.73	88.67	.90	95.48
.57	83.07	.74	89.04	.91	95.92
.58	83.42	.75	89.42	.92	96.35
.58	83.75	.76	89.80	.93	96.79
.60	84.08	.77	90.18	.94	97.24
.61	84.42	.78	90.57	.95	97.69
.62	84.76	.79	90.96		

TABLE II.

Connecting purity of massecuite and purity of resulting molasses when the Brix of the massecuite is constant at 90 and solubility of sugar in molasses is 2.0.

Purity Massecuite	Purity Molasses	Purity Massecuite	Purity Molasses
75	44.44	86	58.82
76	45.45	87	60.60
77	46.51	88	62.50
78	47.62	89	64.51
79	48.78	90	66.67
80	50.00	91	68.96
81	51.28	92	71.43
82	52.63	93	74.07
83	54.06	94	76.92
84	55.55	95	80.00
85	57.14		

TABLE III.

Solubility of Sugar in Pan		Purity of Molasses with Solubility, 2.0													
		38	39	40	41	42	43	44	45	46	47	48	49	50	
2.7	84.93	84.65	84.37	84.14	83.48	83.37	83.31	83.05	82.80	82.55	82.30	82.06	81.81		
2.8	85.15	84.88	84.62	84.35	84.09	83.83	83.58	83.33	83.09	82.85	82.61	82.37	82.14		
2.9	85.37	85.11	84.85	84.59	84.34	84.09	83.85	83.61	83.37	83.13	82.90	82.65	82.46		
3.0	85.58	85.33	85.07	84.82	84.58	84.34	84.10	83.87	83.64	83.42	83.19	82.98	82.76		
3.1	85.79	85.54	85.29	85.05	84.81	84.58	84.35	84.13	83.91	83.69	83.47	83.26	83.05		
3.2	85.99	85.75	85.51	85.27	85.04	84.82	84.60	84.38	84.16	83.95	83.74	83.53	83.33		
3.3	86.18	85.95	85.72	85.49	85.26	85.04	84.83	84.62	84.41	84.20	84.00	83.80	83.60		
3.4	86.37	86.14	85.91	85.69	85.47	85.26	85.05	84.85	84.65	84.45	84.25	84.06	83.87		
3.5	86.55	86.33	86.11	85.89	85.68	85.48	85.27	85.07	84.88	84.70	84.50	84.31	84.13		
3.6	86.73	86.52	86.31	86.09	85.89	85.69	85.49	85.29	85.10	84.92	84.73	84.55	84.37		
3.7	86.90	86.69	86.49	86.29	86.09	85.89	85.69	85.50	85.32	85.14	84.97	84.79	84.62		
3.8	87.07	86.87	86.67	86.47	86.27	86.08	85.89	85.71	85.53	85.36	85.18	85.02	84.85		
3.9	87.24	87.04	86.84	86.65	86.46	86.27	86.09	85.92	85.74	85.57	85.40	85.23	85.07		
4.0	87.40	87.20	87.01	86.83	86.64	86.46	86.11	86.11	85.94	85.78	85.61	85.45	85.29		

TABLE OF THE BOILING POINTS OF WATER UNDER REDUCED PRESSURE.

Pressure in inches of Mercury	Vacuum in inches of Mercury	Boiling Point F. deg.	Pressure in inches of Mercury	Vacuum in inches of Mercury	Boiling Point F. deg.
1.	28.9	79.6	3.5	26.4	120.8
1.1	28.8	82.5	3.6	26.3	121.8
1.2	28.7	85.2	3.7	26.2	122.8
1.3	28.6	87.7	3.8	26.1	123.8
1.4	28.5	90.0	3.9	26.0	124.7
1.5	28.4	92.2	4.0	25.9	125.6
1.6	28.3	94.2	4.1	25.8	126.6
1.7	28.2	96.2	4.2	25.7	127.5
1.8	28.1	98.1	4.3	25.6	128.3
1.9	28.0	99.8	4.4	25.5	129.2
2.0	27.9	101.5	4.5	25.4	130.0
2.1	27.8	103.1	4.6	25.3	130.8
2.2	27.7	104.7	4.7	25.2	131.6
2.3	27.6	106.2	4.8	25.1	132.4
2.4	27.5	107.6	4.9	25.0	133.2
2.5	27.4	109.0	5.0	24.9	133.9
2.6	27.3	110.4	5.1	24.8	134.7
2.7	27.2	111.7	5.2	24.7	135.4
2.8	27.1	112.9	5.3	24.6	136.2
2.9	27.0	114.7	5.4	24.5	136.9
3.0	26.9	115.3	5.5	24.4	137.6
3.1	26.8	116.4	5.6	24.3	138.3
3.2	26.7	117.6	5.7	24.2	138.9
3.3	26.6	118.7	5.8	24.1	139.6
3.4	26.5	119.8	5.9	24.0	140.3

TABLE OF THE ELEVATION OF THE BOILING POINT OF SUGAR SOLUTIONS.

(Claassen-Frentzel Deutsche Vereinzeitschrift, 1893, p. 267.)

Percent Sugar	Elevation of the boiling point F°	Percent Sugar	Elevation of the boiling point F°
75.	13.2	86.75	31.1
75.5	13.7	87.	31.8
76.	14.2	87.25	32.5
76.5	14.8	87.5	33.2
77.	15.3	87.75	33.9
77.5	15.8	88.	34.6
78.	16.4	88.25	35.3
78.5	16.9	88.5	36.0
79.	17.5	88.75	36.7
79.5	18.0	89.	37.5
80.	18.6	89.25	38.3
80.5	19.3	89.5	39.1
81.	19.9	89.75	39.9
81.5	20.5	90.	40.7
82.	21.2	90.25	41.5
82.5	22.0	90.5	42.4
83.	22.7	90.75	43.2
83.5	23.6	91.	44.1
84.	24.7	91.25	45.1
84.5	25.7	91.5	46.3
85.	26.8	91.75	47.7
85.5	27.9	92.	50.2
86.	29.2		
86.25	29.8		
86.5	30.4		











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**DIVISION OF AGRICULTURE AND CHEMISTRY.**

**BULLETIN NO. 21.**

**REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION**

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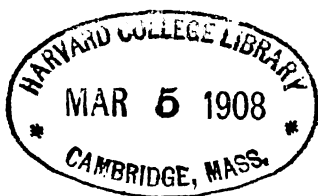
**Evaporator Scale.**

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**BY S. S. PECK.**

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**HONOLULU, T. H.  
1908**



## LETTER OF TRANSMITTAL.

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To the Experiment Station Committee of the Hawaiian Sugar  
Planters' Association, Honolulu, T. H.

Dear Sirs:—I, herewith, submit for publication as Bulletin  
No. 21, of the Division of Agriculture and Chemistry, an article  
entitled "Evaporator Scale." This article has been prepared by  
Mr. S. S. Peck, First Assistant Chemist of this Division.

Yours very respectfully,

C. F. ECKART,

Director, Division of Agriculture and Chemistry.

Honolulu, Hawaii, January 16th, 1908.



## EVAPORATOR SCALE.

---

BY S. S. PECK.

During recent years, much work has been accomplished by chemists engaged in research work in establishing the solubility of salts in water, in solutions of other salts, and in water with insoluble bodies held in suspension. The general result of these investigations has been, with few exceptions, to establish the fact that the solubility of an electrolyte in an aqueous solution of another electrolyte containing a common ion is depressed, the difference in each case depending on the temperature and concentration of the solvent, the mass relation between the solute and solvent, and also the time necessary to produce a condition of saturation. Amongst other lines of chemical research, agricultural chemistry has received considerable assistance in the solution of some of its problems from the investigations of Warrington, Cameron, Seidell, Bell, and many others, on the solubility of the various phosphates of lime, alumina and iron, as well as that of the sulphate of calcium, in water under different conditions of temperature, time and concentration, and in solutions of salts both with and without a common ion. The predominating constituents in evaporator scale are, in addition to organic matter and silica, the sulphate and phosphate of calcium. With a view of ascertaining whether the results of the investigations mentioned would be of value in lessening the amount of scale formed in or on the tubes of the effects in the mills of Hawaii, the work of this Bulletin was undertaken. While the results offer no precise solution to this problem, they explain some of the phenomena of scale formation and may contain considerable of interest to other investigators, practical and theoretical, of this question; perhaps giving them a clue which will lead to the discovery of a successful method of treating the juice of the cane which will inhibit to some extent the formation of scale during evaporation.



## SCALE IN OTHER COUNTRIES.

As should be expected, there is a great difference in the composition of the incrustations found in the different bodies of an effect. Analyses of scales by H. Pellet, and given in Deerr's "Sugar and the Sugar Cane," are as follows:

TABLE I.

	First Body	Second Body	Third Body
Water and Organic Matter.....	29.80	26.70	18.60
Silica .....	.40	23.40	69.80
Iron and Alumina .....	3.80	9.98	2.80
Lime .....	46.30	25.80	6.80
Magnesia .....	1.36	.81	1.08
Phosphoric Acid .....	17.10	11.70	trace
Sulphuric Acid .....	.00	.00	trace
Copper .....	trace	trace	trace
Undetermined .....	1.24	1.61	.92

For the purpose of comparison, the percentage composition of the mineral portion of the scales has been calculated.

TABLE II.

	First Body	Second Body	Third Body
Silica .....	.57	31.92	85.75
Iron and Alumina .....	5.41	13.61	3.44
Lime .....	65.95	35.20	8.35
Magnesia .....	1.94	1.11	1.33
Phosphoric Acid .....	24.36	15.96	trace
Sulphuric Acid .....	.00	.00	trace
Undetermined .....	1.77	2.20	1.13

A marked difference exists between these scales and those from Hawaii, especially noticeable being the entire absence of sulphuric acid in the first two bodies and a mere trace in the last, a condition which obtains in none of the samples which were analyzed in this Station, with perhaps the exception of scale number 1 (see page 12, table VII), which is from a third effect, and resembles very closely in both its organic and mineral composition the third body scale reported above. Unfortunately we were not furnished with samples of scale from the first bodies of the effect in this instance, and therefore do not know whether the same uniformity of composition exists with respect to these deposits or not. There is a great increase in the amount of silica from the first to the last body, a phenomenon which is exhibited also in local scales, which can be seen by reference to table VII.

In Java, the composition of scale has received considerable attention from Mr. Prinsen Geerligs. In his work on "Cane Sugar and the Process of its Manufacture in Java," he gives the following analyses of scales from a quadruple effect:

TABLE III.

	First Vessel	Second Vessel	Third Vessel	Fourth Vessel
Phosphate of Lime.....	57.85	56.98	15.02	7.49
Sulphate of Lime.....	2.02	1.92	.54	1.65
Carbonate of Lime.....	3.25	4.68	19.55	9.93
Silicate of Lime.....	7.86	13.31	.71	7.02
Oxalate of Lime.....	....	....	11.32	11.27
Iron Oxide .....	2.03	1.53	2.31	2.58
Combustible Matter .....	20.37	13.41	11.04	5.08
Silica .....	7.79	7.43	39.26	54.34

These scales show the same increase of silica, and corresponding decrease of phosphoric acid from the first to the last body as do most of the local scales.

In the International Sugar Journal, 1906, there appeared an article by the same writer and H. Tervooren on scale in evapora-

tors, in which analyses are given of scales originating with juices which had been clarified by defecation with minimum lime, with much lime and subsequent saturation with sulphurous acid, by double and single carbonation, and finally by combined defecation, carbonation, and sulphitation. The figures of the ordinary defecation and single carbonation are presented in tables IV and V as being those which have some relation to the investigations undertaken in this laboratory, and as bearing on some of the conclusions, regarding the presence of phosphoric acid in the scale, reached by the Java chemists.

TABLE IV.

SCALE FROM DEFECTION WITH MINIMUM LIME.				
	First Body	Second Body	Third Body	Fourth Body
Loss on Incineration.....	22.28	25.97	31.62	39.91
Silica .....	5.64	14.26	41.75	18.45
Phosphoric Acid .....	29.25	22.12	9.83	2.70
Sulphuric Acid .....	1.90	2.31	.45	.26
Iron Oxide .....	1.47	2.20	.76	1.69
Alumina .....	.30	.39	.13	.81
Lime .....	39.13	31.96	13.97	23.42
Nitrogen .....	.13	.31	.13	.27

Percentage Composition of Mineral Matter.				
Silica .....	7.26	19.47	62.42	38.98
Iron and Alumina.....	2.28	3.53	1.33	5.28
Lime .....	50.37	43.64	20.88	49.48
Phosphoric Acid .....	37.64	30.20	14.69	5.71
Sulphuric Acid .....	2.45	3.16	.68	.55

TABLE V.

SCALE FROM SINGLE CARBONATION.			
	First Body	Second Body	Third Body
Loss on Incineration.....	34.58	40.63	42.25
Silica .....	24.91	38.99	14.22
Phosphoric Acid .....	.42	.00	.00
Sulphuric Acid .....	.38	.00	.00
Iron Oxide .....	16.32	11.71	4.72
Alumina .....	.86	.44	.00
Lime .....	12.81	4.31	21.47
Nitrogen .....	.41	.17	.13

Percentage Composition of Mineral Matter.			
Silica .....	44.72	70.32	35.19
Iron and Alumina .....	30.84	21.91	11.68
Lime .....	23.00	7.77	53.13
Phosphoric Acid .....	.42	.00	.00
Sulphuric Acid .....	.69	.00	.00

The scales formed during the evaporation of juices defecated with lime correspond to many of the scales in our mills as respects the high content of phosphoric acid and increasing amounts of silica deposited in the latter vessels. Those which have been carbonated show an almost entire absence of both phosphoric and sulphuric acids, and from a comparison of these results amongst themselves and compared also with scums from defecation and carbonation filter-presses, the authors have derived interesting conclusions which we quote at length:

"The figures show that the incrustations in the first "body contained the suspended particles (in the clarified "juice), while the incrustations deposited in the vessels

"where the juice is already more concentrated, were dissolved in the clarified juice. According to Pellet and other authors, the lime contained in calcium aluminate or silicate is gradually liberated during the heating of their solution in juice, leaving insoluble alumina and silica, which latter is to be found in well-nigh every incrustation. \* \* \* We ascertained as a result of special investigations that calcium phosphate is very sparingly soluble in saccharine liquids, and no more soluble in an acid medium than a neutral or alkaline one, so that only very little calcium phosphate can be deposited from a real solution. When, however, the scales in the first vessels contain much of the salt, it is proof that the calcium phosphate has not been present in a dissolved state, but gelatinous and in suspension. The fact is further confirmed by the knowledge that the juice from carbonation, which is filtered in presses and not merely clarified by subsiding, does not contain appreciable quantities of calcium phosphate."

In an earlier article on molasses in the same periodical, Mr. Prinsen Geerligs also remarks that

"the phosphates of clarified cane juice do not occur in solution, but in suspension, and in cases, as in carbonation juices, where a thorough filtration of the juice is possible, they are more apt to be removed than in the majority of cases, where nine-tenths of the juice is not filtered at all, but only clarified by subsiding. The same thing is true for silica; in the list we find almost total absence of this body in carbonation molasses, while the defecation molasses contains more silica which has escaped the clarification at the outset of manufacture."

#### SCALE FROM EVAPORATORS IN HAWAII.

During the season of 1907, in response to requests from this Station, twenty-nine samples of scale, representing twelve mills, were supplied for analysis. The results are tabulated in tables VI and VII, the mills being designated by letters for future reference.

TABLE VI.

## ANALYSES OF HAWAIIAN SCALES.

Mill	Body	Organic Matter	Mineral Matter	Nitrogen	Carbonic Oxide	Fat Wax, etc
A	Third	30.24	69.76	.73	.00	*
B	"	29.36	70.64	.27	.32	*
C	"	25.49	74.51	.17	.00	*
D	"	22.41	77.59	.10	.04	.22
"	"	20.21	79.79	.16	.00	*
E	Fourth	25.82	74.18	.26	1.14	*
"	Third	42.18	57.82	.90	.00	*
F	First	16.57	83.43	.23	1.46	*
"	Second	29.41	70.59	.44	1.37	*
"	Third	23.20	76.80	.26	1.71	*
"	Fourth	44.15	55.85	.25	1.84	*
G	First	23.99	76.01	.53	1.45	.33
"	Second	28.62	71.38	.52	1.36	.26
"	Third	26.52	73.48	.36	1.33	.41
"	Fourth	37.00	63.00	.34	.55	*
H	First	28.95	71.05	.47	.23	*
"	Second	32.40	67.60	.51	.46	*
"	Third	30.76	69.24	.39	.48	.49
"	Fourth	41.25	58.75	.19	1.25	.60
I	First	34.53	65.47	.78	.79	*
"	Second	29.75	70.25	.62	1.05	*
"	Third	53.48	46.52	.84	.28	*
"	Fourth	54.01	45.99	.29	.50	.22
J	First	35.61	64.39	.31	.00	*
"	Second	50.15	49.85	.46	.56	*
"	First	25.52	74.48	.44	.00	*
"	Second	28.71	71.29	.47	.15	*
"	Third	26.35	73.65	.47	.05	*

\* Not determined.

TABLE VII.

## ANALYSES OF MINERAL MATTER OF SCALES.

Mill	Body	Silica	Iron and Aluminum Oxides	Lime	Magnesia	Phos- phoric Acid	Sulphuric Acid
A	Third	87.41	.91	10.75	.10	trace	.88
B	"	.53	.23	45.34	.08	6.23	47.38
C	"	1.21	.45	39.35	3.40	2.82	52.10
D	"	3.54	.33	43.08	.26	1.10	51.45
"	"	6.17	.28	44.47	.46	1.22	46.02
E	Fourth	11.45	.85	42.71	1.79	1.47	41.64
"	Third	4.23	2.21	53.01	4.30	31.91	3.71
F	First	5.91	1.45	48.33	3.79	38.62	1.60
"	Second	10.43	2.18	44.94	3.37	32.22	6.08
"	Third	11.64	1.03	47.57	2.49	35.04	1.53
"	Fourth	31.20	4.06	33.47	4.74	15.90	10.34
G	First	16.88	4.19	43.08	3.56	29.70	2.07
"	Second	17.48	3.84	40.03	7.12	28.65	2.08
"	Third	17.07	3.76	42.94	3.19	29.54	2.97
"	Fourth	52.51	3.05	25.24	2.55	9.43	6.70
H	First	.38	3.15	46.98	2.83	43.94	3.12
"	Second	.36	3.42	51.44	2.51	40.00	1.79
"	Third	2.22	3.39	49.97	2.62	39.31	1.78
"	Fourth	7.33	1.00	46.48	4.23	38.62	1.86
I	First	1.36	2.28	51.22	4.52	37.64	2.22
"	Second	5.80	2.45	51.65	3.20	33.77	3.00
"	Third	3.57	2.52	58.37	1.60	28.59	5.08
"	Fourth	24.65	.77	61.95	1.22	8.00	3.44
J	First	17.08	2.32	44.59	.75	8.98	26.60
"	Second	40.86	3.48	47.06	2.09	4.20	1.74
"	First	4.04	2.75	47.95	4.86	38.14	2.11
"	Second	8.31	1.44	44.02	4.12	39.29	2.54
"	Third	36.21	.84	31.87	2.04	25.71	2.74

Some of the samples of scale were accompanied by information regarding method of clarification, etc., which is herewith presented in condensed form.

*Mill "B."* Standard effects; open pan clarification; low grade sugars mixed with clarified juice, then settled out and taken through the effects; press juice used for remelting low grade sugars; no sand filters; variety of cane mainly Yellow Caledonia.

*Mill "D."* Standard effects; superheater; low grade sugars not reclarified; press juice goes directly into the triple effects; no sand filters; Lahaina cane; scale found in the third body only. At the time the sample was taken, the effects had not been cleaned for one month, and scale was particularly heavy because juice of exceptionally low purity had been evaporated during this period. Scale is present in such quantities in a measure because of the density to which the juice is evaporated, namely, in the neighborhood of 65° Brix. The effect of scale is somewhat counteracted by the fact that lime is added only to neutrality.

*Mill "F."* Lillie quadruple effects; superheater and intermediate settlers; juice limed to neutrality, no clarifying agent other than lime employed; sand filters used; press juice mixes with clear juice from the settlers as it enters the sand filters; remelted low grade sugars reclarified; Lahaina cane; considerable trouble with scale formerly when the juice used to be sulphured; evaporators boiled out once a week with soda-ash and afterwards with muriatic acid; also use "Evaporator Compound" in place of soda with good effect.

*Mill "H."* Lillie quadruple effect; alkaline clarification with lime only; closed heaters and intermittent settlers; sugars not remelted; press juice mixed with mill juice; Lahaina cane; scale formed principally in first and fourth bodies, that in first body being much harder than that in fourth; very little scale in second and third bodies.

*Mill "I."* Standard effects; lime to neutrality; superheaters and intermittent settling tanks; no sand filters; press juice run into effect supply tanks; remelts not clarified; Lahaina cane.

*Mill "J."* Lillie and standard effects (the first two in the tables are from the standard, and the other three from the Lillie);



clarified with lime only; superheater; no intermittent settlers; no sand filters; remelted low grade sugars not reclarified; press juice returned into first juice; Yellow Caledonia cane.

The scales were all scraped from the tubes previous to any treatment by soda or acid. Some of them contained considerable copper, indicating in a measure the difficulty which was experienced in removing the incrustations, the amount varying from nothing in those scales consisting principally of sulphate of calcium to 13.51% in the scale from the third effect in Mill "E." The analyses presented are all calculated to copper-free basis.

The deposits can be generally classified as silicate, sulphate, and phosphate scales. The silicate and sulphate scales were of a white or light gray color, and in thin sheets or laminae. The others of a black to dark gray those from the latter bodies being much lighter than those from the first.

#### SILICATE SCALES.

As with the scales reported by Pellet and Prinsen Geerligs, the percentage of silica increases from the third to the last body. These scales, especially when principally aluminum silicate, are hard and smooth and offer an immense resistance to heat transmission, it having been estimated that they possess a hundred times less conducting power than brass. The silica comes not only from the juice itself, but also frequently from the lime used in clarification. It has been proposed, in order to eliminate this danger of contaminating the juice with this unwelcome substance, to slake the lime, using considerable water, allow it to settle, and decant and discard the supernatant liquid. Claasen criticises this method, calling attention to the fact that

"most varieties of lime contain scarcely any impurities  
 "which are soluble in water, and of such only the salts  
 "of the alkalies are worth considering, for those constituents of lime which are difficultly soluble in  
 "water, or dissolve very slowly, such as, for instance,  
 "silicate of lime and alumina, will never be satisfactorily  
 "removed, for the simple reason that they are much more  
 "soluble in sugar solution than they are in pure water."

Experiments conducted to show the solubility of ferric oxide, alumina, and silica contained in quick-lime when in hot

sugar solution show that as soon as the alkalinity was lowered to between 0.15 and 0.07, the percentages of lime and alumina were also less. The solubility of silicic acid, however, remained nearly constant at variable alkalinities. These deposits resist the action of acids, but are partly dissolved by the action of boiling soda solution. Sometimes this fails to remove it, and mechanical scraping must be resorted to.

### SULPHATE SCALES.

The list of scales contains six which consist principally of sulphate of calcium. The sulphuric acid comes entirely from the juices of the cane, no sulphurous acid being used in the clarification; the extent to which it is present must depend on the character of the soil, the nature of the fertilizers applied, or the property of the cane or of different varieties of cane in absorbing the sulphuric acid radical from the soil. However, a study of the analyses of soils from the districts represented reveals no marked difference in their respective contents of sulphuric acid. From fertilizers, they all receive approximately the same amounts of soluble sulphates; sulphate of ammonia, sulphate of potash, and sulphate of calcium in superphosphates, being always present. The fact that some scales are formed with mineral matter consisting principally of sulphate of calcium may be due to two causes, 1st, that the style of evaporators used, whether submerged tube or film, affects the nature of the incrustation deposited; or, 2nd, that in certain districts, canes, of the same or different variety, have a greater selective power for the sulphuric acid radical than in others; for given the same amount of sulphuric anhydride in the juices as they enter the effects, it would be supposed from the very nature of the changing solubility of calcium sulphate, that the incrustation in the last body would be largely composed of that salt. A certain increase is indeed to be seen; thus, in Mill "F" the percentage of sulphuric acid increases from 1.60 per cent. in the first to 10.34 per cent. in the fourth body, and in Mill "G" from 2.07 per cent. to 6.70 per cent. On the other hand, in Mills "H" and "I" there is no appreciable difference. Two years ago a scale was analyzed which came from Mill "B," and also a deposit from molasses from the same source, with results as follows:

	Scale	Molasses Deposit
Silica .....	.17	2.11
Lime .....	42.87	41.65
Magnesia .....	.60	.25
Phosphoric Acid .....	9.48	4.00
Sulphuric Acid .....	41.76	49.55

It will be seen that the composition of the scale in this instance is practically constant, and not due to any seasonal accident or peculiarity of the juices.

#### SOLUBILITY OF SULPHATE OF CALCIUM IN PURE SOLUTIONS.

Sulphate of calcium, which is anhydrous gypsum, is more soluble in cold water than in hot. The results as published by different investigators vary greatly owing to the tendency of the salt to form supersaturated solutions. The maximum concentration exists at about  $37.5^{\circ}$  Centigrade ( $99.5^{\circ}$  Fahrenheit), when a liter contains 2.15 grams, decreasing to 1.798 grams at boiling temperature. The presence of other salts affects the solubility differently, those containing a common ion decreasing, and those not containing a common ion increasing it. According to Droeze, a liter of a solution containing four grams potassium chloride will dissolve 2.32 grams at  $21^{\circ}$  C., while with the concentration increased to 80 grams of the chloride per liter, 5.84 grams are dissolved. Sugar likewise affects the solubility. In 1866 Sostmann gave results showing that a 67 per cent. solution of sugar would contain 4.94 grams of the sulphate in a liter. Later researches have given results quite to the contrary. G. Bruhns (Centr. Zuckerindustrie) shows that the solubility decreases instead of increases with the concentration of the sugar during evaporation and boiling, and that both with neutral and alkaline juices, a separation of gypsum in after products must take place. Stolle has also published a table from which the following figures are taken:

TABLE VIII.

SOLUBILITY OF SULPHATE OF CALCIUM IN SUGAR SOLUTIONS AT DIFFERENT TEMPERATURES.

Per Cent. Sugar	Grams of Calcium Sulphate in 1000 grams solution.		
	30° C. (86° F.)	50° C. (122° F.)	70° C. (158° F.)
0	....	1.733	1.655
10	2.045	1.733	1.576
20	1.811	1.421	1.421
42	1.031	.777	.856
55	....	.505	.369

A series of experiments was made in this laboratory for the purpose of determining the solubility of calcium sulphate in sugar solutions under conditions approximating those existing during the clarification of juices; also, for comparison, in solutions without sugar and at room temperature. For this purpose, a strength of sugar solution of 13 per cent. sucrose was adopted, this being the average of the mixed juices in our mills; and of potassium chloride, a solution containing 2.50 grams to the litre, this being about the average content of this salt in Island juices. The solubility was determined at room and boiling temperature. According to Goldammer, water is fully saturated with calcium sulphate by shaking it with the finely divided substance for five minutes. However, it was thought safer to allow the contact to last for thirty minutes. Two grams of chemically pure calcium sulphate were placed in 250 cubic centimeters of distilled water free of carbonic oxide, and in solutions of sugar and potassium chloride, and shaken at frequent intervals during half an hour. Other equal portions were submitted to similar treatment with boiling water, the flasks being connected with reflux condensers, so as to permit of no loss by evaporation.

TABLE IX.

SOLUBILITY OF CALCIUM SULPHATE IN AQUEOUS  
SOLUTIONS.

Solvent.	Grams Calcium Sulphate per Liter.	
	27° C.	100° C.
Water .....	2.100	1.792
Water and Potassium Chloride..	2.538	2.212
Water and Sugar.....	1.789	1.465
Water, Pot. Chloride and Sugar..	2.171	1.883

This table shows that the solubility is raised by the presence of potassium chloride, and depressed by heat or sucrose under every condition, and in nearly the same proportions.

In table XIV will be found analyses of juices showing their content of sulphuric acid, the average of the clarified juices being 1.461 grams per liter. This acid radical is combined principally with potassium and magnesium as their sulphates, and to a lesser extent with calcium as sulphate of calcium. Cameron and Breazeale (Journal of Physical Chemistry) have shown that calcium sulphate is less soluble in solutions of potassium and magnesium sulphates than in water, the solubility decreasing with the concentration of the solvent salts. But potassium chloride is also present in the juices, and the solubility of the calcium sulphate is greater in its solutions than in water, increasing proportionately with the amount of the chloride present. We have then an explanation of a two-fold action taking place in the evaporators,—the tendency of the calcium sulphate to be thrown out of solution, due to the increasing concentration of the sucrose and the sulphates of potassium and magnesium, counteracted slightly by the increasing solubility of the gypsum in the more concentrated potassium chloride solution. Unfortunately, the rate of solution is greatly inferior to that of precipitation, and sulphate deposits or scales result.

A juice clarified in the laboratory with a slight excess of lime contained 0.339 grams of calcium sulphate per liter. An ef-

fect, then, which takes care of 600,000 gallons of juice of a similar composition a week would have 769.95 kilograms of this substance passing through it. If this juice, originating with 13.48 per cent. sucrose, were evaporated to 55 per cent. sucrose, there would result 118,176 gallons, which, from table VIII, would, at 158° F. be saturated with 165.07 kilograms of the lime sulphate, leaving 604.9 kilograms to be precipitated, either as a deposit from the syrup or after products, or as incrustation on the various tubes, principally on those of the last vessel. If the syrup leaves the last body with 42 per cent. sucrose, there would result 166,184 gallons, which at the same temperature would contain 538.5 kilograms of sulphate of calcium, leaving 231.45 kilograms to be deposited. In other words, the greater the concentration, the larger will be the amount of lime sulphate liable to be deposited as scale; an increase of eight per cent. in evaporation increasing the amount of scale-forming deposit by 161.3 per cent. Of course, not all of the sulphate of calcium that is rendered insoluble is deposited on the tubes, a large part settling out later in the syrup tanks, and also from the molasses subsequent to blowing up. Of that portion forming scale, a small proportion will be found in the first bodies, but the greater portion in the last, since the tendency to form incrustation will be greatly augmented by the greater viscosity and consequent slower movement of the syrup. That such an increase in sulphate scale does result from a higher concentration of the juice is evidenced by the experience of Mill "D." The figures given above are no great exaggeration of possible conditions. A scale similar to one of the samples received and a thirty-second of an inch in thickness distributed evenly over the tubes of an effect having 1,000 square feet evaporating surface, will weigh 199,735 grams, and with a content of 57 per cent. calcium sulphate will contain 113,849 grams of that salt; while if of double this thickness, it will weigh twice this amount, or 227,798 grams.

It is noticeable that all the sulphate scales originate in vessels of the submerged tube type. However, not all of this type give a sulphate scale, as Mill "I" has a vertical effect. Unfortunately we have received but one set of samples from a mill where both styles of evaporation are in use, viz: Mill "J." Here the exceptional condition is presented of a scale from the first body con-

taining a greater percentage of sulphuric acid than that from the second. Nevertheless, the first body of this vertical effect produces a scale with ten times as much of this radical as does any of the bodies of the Lillie. No positive explanation can be offered at this time of this phenomenon, but it is doubtless due either to the different compositions of the respective juices, or their more rapid circulation in the film evaporators, not offering time for the scaly deposit of calcium sulphate to adhere.

### REMOVAL OF SULPHATE SCALE.

Gypsum can be dissolved by the action of dilute muriatic acid only after long continued boiling, a condition which is not favorable for the long life of the metal containers, although a mixture of the acid with five times its volume of water will not affect copper or brass if it does not consist of more than fifty per cent. zinc. Zinc itself and iron, however, are quickly dissolved. The solubility of gypsum in dilute hydrochloric acid at boiling temperature is as follows:

Grams Hydrochloric per liter	Grams Calcium Sulphate per liter
.77	11.209
3.06	31.780
6.12	46.902

The better plan, however, is to boil with a dilute solution of sodium carbonate, which has the two-fold action of disintegrating the scale by dissolving the fats and loosening up the other organic matter, and of converting the calcium sulphate into calcium carbonate, which is readily dissolved by weak muriatic acid.

Lime sulphate is also more soluble in a solution of common salt than in water, one containing 20 per cent. sodium chloride dissolving 8.23 grams per liter at 20° C. A rise in temperature lowers the solubility until at 100° C. only 2.5 grams remain in solution. It is also soluble in many other salts, as ammonium sulphate and sodium thiosulphate. An endeavor has been made

to use these compounds in removing this incrustation from rum stills, but without any success.\*

Lime as sulphate can be removed from the juices before evaporation partially by sodium carbonate, whereby sodium sulphate and the more innocuous calcium carbonate result; or almost completely by treatment with barium salts. Neither of these methods is to be recommended, the latter especially on account of the poisonous nature of barium compounds.

### PHOSPHATE SCALES.

The balance of the scales are composed principally of lime phosphate. The solubility of the different phosphates of lime has received extended study. That of tri-calcic phosphate, the insoluble form in which it is precipitated from the juice during defecation, has been greatly complicated by the fact that a true solution of this substance does not take place when it is placed in contact with water, but a partial decomposition results. The extent of this decomposition or hydrolysis varies with the relative masses of the solvent and the solute, the time of contact, temperature, and completeness of agitation. The products of the decomposition are hydroxide of calcium and free phosphoric acid, the latter going entirely into solution, the former partly, the remainder forming with the calcium phosphate left a basic phosphate. The acid radical is dissolved out in far greater proportion than the lime, so that the resulting solution always has an acid reaction.

In experiments with a pure preparation of tri-calcic phosphate, Warrington showed that after boiling it with water for three hours, the solution contained three times as much phosphoric acid as calcium, although the original contained a little more calcium than required by the formula where the relation between lime and phosphoric acid is as 1 to 0.845.

All the salts of calcium diminish the amount of phosphoric acid going into solution in water. Solutions of potassium chloride up to a certain concentration act likewise, but increase the amount of lime, the solutions, however, still having an acid reaction. Sucrose solutions dissolve the phosphate in inverse proportion to the concentration. The following is from Spencer's Handbook:

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\* A. Urich. International Sugar Journal, December, 1901.



Strength of Sugar Solution.	Calcium Phosphate Grams per liter.
5 per cent.	.029
10 " "	.028
15 " "	.014
20 " "	.018
25 " "	.005

For the purpose of ascertaining the solubility of the phosphate in sugar solutions, determinations were made in this laboratory with similar solutions to those used in the determinations of the solubility of sulphate of calcium. The necessary length of contact and strength of solutions were determined by preliminary tests, the aim being to obtain concentrations which would allow exact measurements of the elements dissolved. The conditions, then, of the experiments do not pretend to entirely duplicate those obtaining in a mill. The strength of sucrose, 13 per cent., and that of potassium chloride, 0.25 per cent., are derived from the average of many juices. The time of contact was two hours, the cold solutions being shaken at frequent intervals. The boiling was conducted in flasks connected with reflux condensers. There were four series of tests, with water alone, water and potassium chloride, water and sucrose, and water, potassium chloride and sucrose. The solubility was determined both with the phosphate alone and with calcium carbonate suspended in the solvent. Calcium carbonate was selected from the list of compounds which decrease the solubility of the phosphoric acid as being the one that it would be possible to use both economically and practically, if the results warranted it, and as further having no known injurious action on the juice. The sugar used was refined granulated, the ash being determined and proper allowance made in the calculations. The water was carbonic oxide free, and the potassium chloride and calcium carbonate chemically pure. The calcium phosphate was almost exactly correct, as the following analysis shows:

Tricalcic Phosphate .....	91.62 per cent.
Calcium Hydroxide .....	.89 " "
Moisture .....	7.40 " "

The following tables give the amounts of lime and phosphoric acid contained in a liter of solution. In each case the determination was made with 500 cc. of the respective solutions, an amount of the phosphate equivalent to five grams of tri-calcic phosphate, and one gram of calcium carbonate. As stated before, the conditions were exaggerated over what is found during the clarification of juices, but all determinations were carried on under exactly similar conditions, and are strictly comparable.

TABLE X.

## SOLUBILITY OF PHOSPHATE OF CALCIUM IN WATER.

Temperature.	Lime Grams per Liter	Phosphoric Acid Grams per Liter	Reaction N/10 C. C. per Liter
Without Calcium Carbonate			
25° C.	.0053	.0201	3.41 Acid
100° C.	.0055	.0777	19.62 Acid
With Calcium Carbonate			
25° C.	.0342	trace	Neutral
100° C.	.0077	faint trace	Alkaline

Boiling rapidly accelerates the decomposition of the calcium phosphate into free phosphoric acid and basic lime, the former increasing over three fold, while the amount of the latter going into solution remained constant. Addition of calcium carbonate either prevented the solution of the acid, or upon its being released interacted with it forming a fresh precipitate of insoluble calcium phosphate, the amount of phosphoric acid actually in solution not being determinable by ordinary laboratory methods.

There was much more lime dissolved when the carbonate was present, but upon boiling the amount was reduced to almost that of the solution without this addition.

TABLE XI.

SOLUBILITY OF PHOSPHATE OF CALCIUM IN WATER CONTAINING 0.25 PER CENT. POTASSIUM CHLORIDE.

Temperature.	Lime Grams per Liter	Phosphoric Acid Grams per Liter	Reaction N/10 C. C. per Liter
Without Calcium Carbonate			
25° C.	0.0121	0.0221	3.28 Acid
100° C.	0.0116	0.0800	18.67 Acid
With Calcium Carbonate			
25° C.	0.0427	trace	Neutral
100° C.	0.0105	faint trace	Alkaline

A decided increase of lime in solution is effected by the presence of the potassium chloride, the phosphoric acid remaining practically the same. The relative changes are the same as in the previous table.

TABLE XII.

SOLUBILITY OF PHOSPHATE OF CALCIUM IN WATER CONTAINING 13 PER CENT. OF SUGAR.

Temperature.	Lime Grams per Liter	Phosphoric Acid Grams per Liter	Reaction N/10 C. C. per Liter
Without Calcium Carbonate			
25° C.	0.0195	0.0192	3.31 Acid
100° C.	0.0175	0.0726	17.79 Acid
With Calcium Carbonate			
25° C.	0.0386	0.0016	Neutral
100° C.	0.0242	0.00046	Alkaline

The presence of the sucrose increased the amount of lime going into solution, while that of phosphoric acid was slightly lowered where no calcium carbonate was added. While in pure water solution, this compound reduced the amount of the phosphoric acid to a mere trace, in a sugar solution it was retained in determinable quantities. A considerable reduction in the amount, however, is obtained, a comparison between the boiled solutions in the above table showing that the one in which the calcium carbonate was present held less than 0.7 per cent. as much phosphoric acid as the one containing no carbonate.

TABLE XIII.

SOLUBILITY OF PHOSPHATE OF CALCIUM IN WATER CONTAINING 0.25 PER CENT. POTASSIUM CHLORIDE AND 13 PER CENT. SUGAR.

Temperature.	Lime Grams per Liter	Phosphoric Acid Grams per Liter	Reaction N/10 C. C. per Liter
Without Calcium Carbonate			
25° C.	0.0222	0.0227	3.31 Acid
100° C.	0.0233	0.0716	17.55 Acid
With Calcium Carbonate			
25° C.	0.0515	0.00207	Neutral
100° C.	0.0334	0.00095	Alkaline

The results here show a similar relation to table XI as is exhibited between tables X and XII. The phosphoric acid due to the sugar is a little higher than in table XII on account of the presence of potassium chloride, just as in table XI the phosphoric acid in the experiments untreated with calcium carbonate was greater than in the corresponding tests in table X.

It would appear, then, that under the conditions of these experiments a boiling solution containing sucrose will dissolve more phosphoric acid than one without.

Phosphoric acid exists in the juices combined with various bases, iron, alumina, lime, magnesia, and potash. On the addition of lime, lime phosphate is precipitated out of solution along with the other insoluble products of defecation, albumenoids, etc. This precipitated phosphate is in contact with the juice for a brief period, as it passes through the heater or is boiled in the defecators, and on being placed in the settling tanks goes to the bottom along with the other eliminated impurities. The conditions of the experiments are consequently quite different, but it was nevertheless hoped that the presence of calcium carbonate in the juice would effect a more complete separation of insoluble lime phosphate, and a correspondingly diminished amount that would enter the evaporating apparatus. In the carbonation process much less phosphoric acid is found in the scale than in that from the defecation process. This is due, according to Prinsen Geerligs, to the fact that in the former case the juices are filtered and particles in suspension eliminated. It will be shown further on that this may be also due to the fact that such juices are always limed to excess, the alkalinity being reduced afterwards by precipitation of the lime as carbonate by means of carbonic acid gas. There is then so little of phosphates left in the juices, that the increasing concentration in the effects does not cause a precipitation and subsequent deposition of phosphate scale.

### EXPERIMENTS WITH JUICES.

With the object of learning the amount of phosphoric acid retained by a juice after clarification, determinations were made with a juice from Daniel Dupont cane having the following composition:

Brix .....	15.73
Sucrose .....	12.69
Purity .....	80.67
Glucose .....	.60
Glucose Ratio .....	4.73

## Mineral contents:

Soluble Ash, grams per liter.....	4.932
Insoluble Ash, " " " .....	3.760
Total Ash, " " " .....	8.692
Lime, " " " .....	.263
Phosphoric Acid, " " " .....	1.168
Sulphuric Acid, " " " .....	1.278
Chlorine, " " " .....	.212
Acidity, terms of N/10 Acid.....	.256

Equal quantities of this juice were clarified with varying amounts of milk of lime, with the view of having an acid, neutral and alkaline determination. The amount of lime necessary for this purpose was calculated from the acidity, but as will be seen, an insufficient quantity was added to produce neutrality. Duplicates of the acid and neutral clarification were made with 5 grams of calcium carbonate added per liter of juice. In each case the cold juice was tempered with lime until the desired reaction was achieved, the lime carbonate added, brought to a boil, kept at boiling temperature for two minutes, allowed to settle, and filtered through filter paper. The reaction was determined with phenolphthalein. The results are tabulated with the original juice for comparison in tables XIV and XV.

TABLE XIV.

## ANALYSES OF JUICES.

	Brix	Sucrose	Purity	Glucose	Glucose Ratio	Acidity
Original Juice .....	15.73	12.69	80.67	.60	4.73	.256
Acid Clarification...	16.96	14.01	82.61	.68	4.85	.120
Acid Clarification and Lime Carbonate ..	16.89	14.01	82.95	.68	4.85	.112
Neutral Clarification.	16.28	13.45	82.62	.64	4.76	.084
Neutral Clarification and Lime Carbonate	16.09	13.31	82.72	.64	4.81	.068
Alkaline Clarification	16.17	13.48	83.36	.62	4.60	...

TABLE XV.

COMPOSITION OF MINERAL MATTER OF JUICE FROM  
ACID CLARIFICATION.

	Lime only	Lime and Calcium Carbonate
	(Grams per Liter)	
Total Ash .....	7.807	7.521
Soluble Ash .....	5.233	5.081
Insoluble Ash .....	2.574	2.440
Lime .....	.274	.266
Sulphuric Acid .....	1.443	1.523
Phosphoric Acid .....	.593	.591

TABLE XVI.

COMPOSITION OF MINERAL MATTER OF JUICE FROM  
NEUTRAL CLARIFICATION.

	Lime only	Lime and Calcium Carbonate
	(Grams per Liter)	
Total Ash .....	7.474	7.984
Soluble Ash .....	4.970	6.159
Insoluble Ash .....	2.504	1.825
Lime .....	.249	.260
Sulphuric Acid .....	1.426	1.528
Phosphoric Acid .....	.436	.432

TABLE XVII.

COMPOSITION OF MINERAL MATTER OF JUICE FROM  
ALKALINE CLARIFICATION.

	(Grams per Liter)
Total Ash .....	7.008
Soluble Ash .....	5.743
Insoluble Ash .....	1.265
Lime .....	.217
Sulphuric Acid .....	1.385
Phosphoric Acid .....	.065

The clarified juices showed marked differences in the time necessary for complete subsidence, the alkaline settling slowly, the others more rapidly, and of these, the ones containing the lime carbonate being the quicker. As regards the amount of phosphoric acid removed, there was no gain due to the carbonate, the percentages of removal being:

Acid Clarification .....	49.23 per cent.
Acid Clarification and Calcium Carbonate....	49.40 " "
Neutral Clarification .....	62.67 " "
Neutral Clarification and Calcium Carbonate..	63.01 " "
Alkaline Clarification .....	94.43 " "

The lime content of the alkaline juice was a little less than in the others. This has been ascribed to the formation of basic lime salts when juice is limed to excess, whereby calcic salts are thrown out of solution.

For the purpose of obtaining a juice which was strictly neutral a second and more complete series of experiments was planned, in which attention was directed exclusively to the phosphoric acid. As has been pointed out by H. Pellet and Noel Deerr, phenolphthalein is not a reliable indicator as regards the alkalinity of cane juice, one which is neutral to this reagent showing a decided alkaline reaction to litmus. It was suggested to the writer by Mr. Deerr that the color of the juice itself is a valuable guide to its reaction. A fresh lot of juice from the same variety of cane was procured, having the following composition:

Brix .....	16.19
Sucrose .....	13.18
Purity .....	81.41
Acidity .....	.125

Glucose was not determined, since the purity of the juice alone would sufficiently indicate any considerable destruction of sucrose.

The reaction was obtained by preparing mixtures of 20 c. c. of the juice in 250 c. c. of water, and after adding varying quantities of tenth normal soda, observing the reaction with a very delicate litmus paper obtained from Mr. Bartel, chemist of the Wai-luku Sugar Company, and also the color in a 100 c. c. Nessler jar, with the following results:



5	c. c.	N/10 Soda,	distinctly alkaline to litmus,	color	dark	green
4	"	"	"	"	"	"
3.5	"	"	"	"	"	"
3.0	"	"	faintly	"	"	green
2.5	"	"	neutral	"	"	light
2.0	"	"	acid	"	"	yellowish
1.0	"	"	"	"	"	"

Even the first, however, showed no color reaction with phenolphthalein. It was concluded that the 2.5 c. c. brought the juice to neutrality, and from this the acidity of 0.125 deduced. Separate portions of 500 c. c. of juice were clarified with varying amounts of powdered quicklime with and without 2 grams of calcium carbonate, boiling being conducted as before for two minutes and the juice filtered after settling, as follows:

- 0.25 grams of lime,—settled poorly, juice remained cloudy, filtered slowly, reaction acid.
- 0.35 grams of lime,—settled fairly, clarification fair, filtered slowly, reaction acid.
- 0.45 grams of lime,—settled quickly, clarification good, filtered rapidly, reaction acid.
- 0.5 grams of lime,—settled quickly, clarification good, filtered rapidly, reaction acid.
- 0.525 grams of lime,—settled quickly, clarification good, filtered rapidly, reaction neutral.
- 0.55 grams of lime,—settled quickly, clarification good, filtered rapidly, reaction alkaline, color darker than the preceding.
- 0.6 grams of lime,—settled fairly, clarification good, filtered rapidly, reaction distinctly alkaline, color very dark.

No color difference was observable between those with and without calcium carbonate, but the sedimentation was more rapid with the latter. The reaction was first determined with the delicate litmus paper, and in the subsequent determinations of acidity, the juice with 0.525 grams of lime was accepted as being neutral. The reaction of the others was then determined by the amount of tenth normal acid or alkali necessary to bring them to the same depth of color as this standard, observations being made in solutions of the same strength in Nessler jars.

TABLE XVIII.

ANALYSES OF JUICES.					
Lime Grams	Calcium Carbonate Grams	Brix	Sucrose	Purity	Reaction N/10 Solution
..	.	16.19	13.18	81.41	.125 Acid
.25	.	17.06	14.06	82.42	.075 "
.25	2	17.16	14.01	81.64	" "
.35	.	16.50	13.58	82.30	.040 "
.35	2	16.65	13.74	82.52	" "
.45	.	16.96	14.01	82.61	.0038 "
.45	2	16.54	13.66	82.59	" "
.50	.	16.69	13.90	83.28	.0014 "
.50	2	16.69	13.88	83.16	" "
.525	.	16.75	14.04	83.82	Neutral
.525	2	16.75	13.80	82.39	"
.55	.	16.69	14.01	83.94	.0025 Alkaline
.55	2	16.69	13.82	82.80	" "
.60	.	16.53	13.86	83.85	.0056 "
.60	2	16.53	13.78	83.36	" "

A varying but almost regular drop is to be observed in the purities where calcium carbonate was added. It is not believed that this is due to any destruction of sucrose, and calcium carbonate is so slightly soluble as not to be able to cause any noticeable change in this respect. It is hoped that opportunity will later on be presented for further study in this direction.

Analysis of mineral matter was confined entirely to the determination of phosphoric acid. Table XIX shows the amount of phosphoric acid contained in grams per liter, and the percentage removed in each case. All calculations are based on the brix of the original juice.

TABLE XIX.

Lime Grams	Calcium Carbonate Grams	Phosphoric Acid Grams per Liter	Phosphoric Acid Removed per Cent
..	.	1.2122	....
.25	.	.6672	44.96
.25	2	.6629	45.31
.35	.	.4282	64.67
.35	2	.4521	62.70
.45	.	.2229	81.61
.45	2	.1993	83.56
.50	.	.1286	89.39
.50	2	.1281	89.43
.525	.	.0888	92.67
.525	2	.0888	92.67
.55	.	.0670	94.47
.55	2	.0674	94.44
.60	.	.0531	95.62
.60	2	.0406	96.65

It is apparent that notwithstanding the immense restraining action possessed by calcium carbonate on the solubility of calcium phosphate in water or sugar solution, with and without alkaline chlorides, in the briefer period in which it is necessarily in contact with the juice and its precipitate, its effect is practically nil. It is evident, however, that the phosphoric acid found in scales is not entirely due to the suspended matter, but also to that which is in actual solution, since the results given above are from juices which have passed through filter paper. That suspended matter does affect it, there is no doubt. Perhaps a better indicator of the presence of such material is offered by the nitrogen content of the scales, that in the last being generally less than in the first bodies. An analysis of a scale from the Deming superheater in Mill "J" shows this difference more clearly, the nitrogen in the scales from the effects ranging from 0.31 to 0.47 per cent.

## ANALYSIS OF SCALE FROM DEMING.

Organic Matter .....	30.18	per cent.
Mineral Matter .....	69.82	"
Nitrogen .....	1.86	"
Carbonic Oxide .....	.10	"

## MINERAL MATTER.

Silica .....	.24	"
Iron and Aluminum .....	1.01	"
Lime .....	44.96	"
Magnesia .....	6.90	"
Phosphoric Acid .....	46.26	"
Sulphuric Acid .....	.42	"

While the results as regards scale prevention are negative, calcium carbonate does have a beneficial effect as regards rate of sedimentation, and will also produce a better press cake, which can be more readily and completely washed. An attempt has been made to utilize this substance in the treatment of syrup in diffusion plants. In a process patented by Dabrowski and Kaczmarkiewicz, the diffusion syrup is treated with natural powdered carbonate of lime, also with milk of lime. The powdered carbonate of lime is obtained from lime stone, chalk or pure marl. To the syrup is added, with continual stirring, one per cent. or more of carbonate of lime and sufficient milk of lime to impart to the syrup an alkalinity of 0.07. The syrup is afterwards heated to 80° C., whereby the sediment formed is separated more easily. The removal of this sediment gives a freer boiling syrup. What this sediment is composed of is not stated, but in the light of our present knowledge it is reasonable to suppose that it is largely composed of phosphate of calcium, with perhaps some sulphate of calcium which had already separated out from the syrup, but had not been deposited as scale in the effects.

Carbonate of calcium is soluble only to a very small degree in water free from carbonic acid, and less so in solutions of sugar than in water, the degree of solubility lessening with the concentration. It has, as far as known, no deleterious action on sugar; if further researches should show a method of utilizing it whereby the amount of scale formed can be materially reduced, it will be of immense value in increasing the efficiency of the effects.

## REMOVAL OF PHOSPHATE SCALE.

The removal of phosphate scale by solution in boiling acid presents no great difficulty. A previous treatment with soda is always advisable, in order to disintegrate the organic matter, whereby the time necessary to dissolve the scale afterwards with muriatic acid is lessened. A solution of  $\frac{1}{4}$  to 1 per cent. can be used, and boiling for an hour will leave the tubes practically free of incrustations.

### LIME USED IN CLARIFICATION.

Care should be taken that the lime contains but a small percentage of impurities, particularly magnesia and soluble silicates, so that a minimum amount of substances tending to form scale is introduced into the juice.

## METHODS OF MANUFACTURE TENDING TO DIMINISH SCALE.

*Sand Filters.* The use of sand filters prevents in a large measure the formation of scale. The kind of sand used influences to a considerable degree the advantages obtained. At one of the mills using these appliances, an appreciable reduction of scale was noticed after substituting coral sand for quartz sand. It seems probable that during the passage of the juice through the filters, not only was the removal of the suspended matter accomplished as effectually with the coral sand as with that first employed, but that there was also a precipitation or fixation of some of the dissolved phosphates due to their interaction with calcium carbonate, of which the sand is composed. To determine the action of the coral sand on the phosphate contents of the juice, the following experiment was carried out: Four and a half litres of juice from the same cane as was used in the previous determinations were clarified with four grams of lime. The clarified juice settled well, was of a light green color, and showed a slight acidity to litmus. Coral beach sand was prepared by copious washing with distilled water until all soluble matter was removed, and placed in a percolator to a height of four and a half inches. The clarified juice was filtered through filter paper and the usual analyses made. A part was sent through the sand filter, the first runnings being discarded, until the filtered juice

had about the same density as the unfiltered. The rate of percolation was so regulated that the juice was in contact with the sand for about two minutes. The juice had naturally cooled somewhat during the time necessary for filtration through paper, and at the time of emergence from the sand filter was almost at room temperature. The composition of the juices was as follows:

TABLE XX.

COMPOSITION OF JUICES BEFORE AND AFTER FILTRATION THROUGH CORAL SAND.			
	Brix.	Sucrose.	Purity.
Raw Juice .....	16.59	13.63	82.16
Clarified Juice .....	17.16	14.28	83.22
Sand Filtered Juice...	16.63	13.85	83.28

The mineral composition figured to the brix of the raw juice is given in the following table:

TABLE XXI.

MINERAL MATTER OF JUICES BEFORE AND AFTER FILTRATION THROUGH CORAL SAND.				
		Raw Juice.	Filtered Juice.	Sand Filtered Juice.
(Grams per liter.)				
Total	Ash.....	9.240	7.612	7.439
Soluble	" .....	5.524	6.284	6.008
Insoluble	" .....	3.716	1.328	1.431
Lime	.....	.307	.215	.241
Sulphuric	Acid.....	1.364	1.287	1.226
Phosphoric	" .....	1.212	.185	.0859
Silica	.....	.470	.213	.204

The action of the sand in removing phosphoric acid is very marked, the juice from the sand filter containing less than one-half as much of this element as that not filtered through sand. Where 84.73 per cent. of phosphoric acid was removed by the action of lime alone, 92.91 per cent. was taken out by the action of the lime and sand filter combined. In addition to the superiority of coral over quartz sand in this respect, is also the question of cost, an abundance of coral sand being available to most of our mills.

*Intermediate Settling Tanks.* Where the juice settles slowly after clarification, much of the sediment which would otherwise be carried into the evaporators can be gotten rid of by use of intermediate settlers. A continuous settler in one of our mills is ingeniously contrived from the tanks or boxes formerly belonging to a Taylor bag filter. These are combined into one large tank and divided into compartments by partitions of wood about twelve inches high running across the bottom perpendicular to the direction of the flow of the juice. This enters at one end and is continually discharged at the other, gradually depositing its sediment as it passes over the successive partitions, until that leaving the apparatus is almost perfectly clear. While not producing as brilliant a juice as sand filters, a material reduction of suspended matter is effected at a very low cost of time and apparatus.

## METHODS OF MANUFACTURE TENDING TO INCREASE SCALE.

1. It is self-evident that a juice which settles poorly will make scale; in the absence of sand filters or intermediate settlers, clarification must be improved to avoid this. A very obstinate juice can be made to settle by the well-known method of over-liming and the addition of clariphos or a similar phosphoric acid combination, the heavy precipitate of calcium phosphate settling rapidly and carrying down with it most of the suspended matter. Care must be taken that the juice is left neutral or slightly alkaline, otherwise the object aimed at will be missed.

2. Returning remelted low grade sugars into the evaporators without previous clarification, it is obvious, introduces many impurities into the effects which would be avoided if the remelts

had first been sent through the clarification process with the mill juice. The objection has been urged against this that an increased sucrose content in the press cake is produced, or a greater volume of water used in the washing thereof made necessary; but if the remelt is allowed to mix slowly and continuously with the mill juice, this need not be feared.

3. Mixing press juice with the clarified juice just before it enters the effects is very liable to produce an immense amount of scale, particularly in the first body. Usually the scums are given additional lime and boiled up, before they are pumped into the filter presses, so that the press juice is of a greater alkalinity than the juices from which they originated. Any juice, unless limed to a considerable alkalinity will give a further precipitation when more lime is added; so that upon the admixture of the over-limed press juice with the neutral or under-limed clarified juice, a fresh precipitate is formed. Without any opportunity for depositing, this precipitate enters directly into the first vessel, with disastrous results to it as regards scale. It would seem that in such cases all difficulty might be avoided by a more heavy liming of the juice for clarification. With many juices, however, it has been found necessary, in order to produce good settling or good boiling qualities, to keep them neutral, or even slightly acid. It is much better to run the press juice, whether it has been used for remelting low grade sugars or not, into the mill juice for re-clarification, or rather for re-settling.

The writer desires to express his obligations to Mr. A. E. Jordan, who assisted in the analytical work, and to the following publications, from which he quoted freely:

"International Sugar Journal."

"Sugar and the Sugar Cane," Noel Deerr.

"Beet Sugar Manufacture," Claasen; Hall & Rolfe's translation.

"Beet Sugar Manufacturing and Refining," Ware.

"Journal of the American Chemical Society,"

and various bulletins of the Bureau of Soils, U. S. Department of Agriculture.











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**BULLETIN NO. 22.**

**REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION**

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**A Theory of the Extraction  
of Juice by Milling.**

---

**BY NOËL DEERR.**

---

**HONOLULU, T. H.  
1908**



*512 5000 512*

## LETTER OF TRANSMITTAL.

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To the Experiment Station Committee of the Hawaiian Sugar Planters' Association, Honolulu, Hawaii.

Dear Sirs:—I, herewith, submit for publication as Bulletin No. 22 of the Division of Agriculture and Chemistry, an article entitled: "A Theory of the Extraction of Juice by Milling." This article has been prepared by Mr. Noël Deerr, Assistant Director of this Division.

Yours very truly,

C. F. ECKART,

Director, Division of Agriculture and Chemistry.

Honolulu, Hawaii, January 28, 1908.





# A THEORY OF THE EXTRACTION OF JUICE BY MILLING.

By Noël Deerr.

It is intended in this Bulletin to follow out algebraically the processes in general use applied to the extraction of sugar from canes, and to obtain expressions representing what results when different methods of working are employed under ideal conditions, that is to say, when the water used in saturation processes works at its maximum efficiency. Results so obtained will be strictly comparative amongst themselves, although they will not represent the imperfect conditions holding in the actual factory work.

The process adopted to extract the sugar from the canes may be divided into two parts:

1. The crushing of the canes without the addition of water or other diluent; this I shall refer to as the "Dry crushing."
2. The extraction of the residual juice left after the dry crushing by the saturation of the dry crushed bagasse with water or diluted juice, and subsequent recrushing. This I shall refer to as the "Saturated crushing."

In the simple algebraic formulae developed here  $f$  denotes the fibre per unit weight of cane,  $m$  denotes the fibre per unit weight of bagasse, and  $w$  denotes the water added in the saturation of the bagasse per unit weight of cane.

*Preliminary considerations:* If  $f$  and  $m$  have the significance already attributed to them, then the weight of bagasse per unit weight of cane is  $\frac{f}{m}$  and the weight of the juice expressed is  $\frac{m-f}{m}$ . The weight of juice in unit weight of cane is  $1-f$ , so that the juice extracted per unit weight of juice in the cane is  $\frac{m-f}{m(1-f)}$ .

The weight of juice remaining in the bagasse is  $\frac{f(1-m)}{m}$ , and the juice lost in the bagasse per unit weight of juice in the cane is  $\frac{f(1-m)}{m(1-f)}$ . Owing to the first expressed juice being richer

than that left in the bagasse, the extraction per 100 sucrose in cane is higher than is indicated by the formula  $\frac{m-f}{m(1-f)}$ .

If the sugar value of the expressed juice is indicated by unity and the sugar value of the residual juice by  $a$ , then the sugar value of all the juice in the cane is represented by

$$\frac{m-f}{m} + \frac{af(1-m)}{m} = \frac{m+af-f-afm}{m}$$

and the extraction will be given by the formula

$$\frac{m-f}{m} + \frac{m+af-f-afm}{m} = \frac{m-f}{m+af-f-afm}$$

With canes containing 12% of fibre and thereabouts, and dry crushed to 45% of fibre or thereabouts, it will be found on trial that the residual juice in the bagasse contains a percentage of sugar about 85% of that contained in the expressed juice; if, then, for  $a$  .85 be substituted it will be found that the extraction of sucrose is from 2.5% to 3.0% higher than is indicated by the formula  $\frac{m-f}{m(1-f)}$ . The variation depends on the amount of fibre in the cane, and on the relation between expressed and residual juice.

As typical of the results obtained in a modern mill I take 45% of fibre in dry crushed bagasse as representative of good modern work. In table I, I have calculated out the extraction obtained, when canes containing 10% to 14% of fibre are dry crushed to 45% of fibre, allowing an increase in the extraction of 3% over and above that indicated by the formula  $\frac{m-f}{m(1-f)}$ , so as to allow for the decreased sugar value of the residual juice in the bagasse.

*The effect of the added water.*

To  $\frac{f}{m}$  bagasse obtained in the dry crushing let  $w$  water be added per unit weight of cane; let this water mix completely with the residual juice in the bagasse, the weight of which per unit of cane is  $\frac{f(1-m)}{m}$ . The weight of the bagasse and water is then

$$\frac{f}{m} + w = \frac{f + wm}{m}$$

and the residual juice in this bagasse is as has already been shown  $\frac{f(1-m)}{m}$  so that the weight of diluted juice is

$$\frac{f(1-m)}{m} + w = \frac{f + wm - fm}{m}$$

If this saturated bagasse be crushed until it again contains  $m$  nbre per unit weight of bagasse, evidently the weight of diluted juice obtained is  $w$  and the proportion obtained of that originally present is

$$w \div \frac{f + wm - fm}{m} = \frac{wm}{f + wm - fm}$$

If the content of fibre in the dry crushed bagasse be  $m$ , and in the saturated crushed bagasse  $m'$ , the proportion of sugar obtained of that actually present may be found in this way. To  $\frac{f}{m}$  bagasse let  $w$  water be added; as before the weight of bagasse now is  $\frac{f + wm}{m}$ , and it contains  $\frac{fm}{f + wm}$  fibre. Let this bagasse be crushed to  $m'$  fibre, when the weight of the bagasse becomes  $\frac{f}{m'}$  and the weight of the diluted juice obtained is  $\frac{f + wm}{m} - \frac{f}{m'} = \frac{m'(f + wm) - fm}{mm'}$ . The whole weight of diluted

juice in the saturated bagasse is  $\frac{f + wm - fm}{m}$ , so that the proportion obtained is  $\frac{m'(f + wm) - fm}{mm'} \div \frac{f + wm - fm}{m} = \frac{m'(f + wm) - fm}{m'(f + wm - fm)}$ .

These expressions may be used as the basis of a theory of the extraction of sugar from canes and incidentally to form a system of control.

### *Single maceration.*

By this term I mean a process where the canes after the preliminary dry crushing are saturated once with water and again crushed, as opposed to a process entailing the return of the diluted third mill juices. I mentioned above that I took 45% of fibre in dry crushed bagasse as typical of good modern work; in the crop of 1907 the average fibre in the final bagasse in 25 Hawaiian factories was 49.65%, and I shall take 50% of fibre in the final bagasse as representative of good modern work. In Table No. II, I have calculated out what proportion of the sugar in the cane is

obtained by a single maceration, with complete admixture, for different amounts of added water, in all cases after the canes have been dry crushed to 45% of fibre and after allowance as already detailed has been made for the decreased sugar value of the residual juice in the bagasse. It follows as a result of the equation, and as can be seen from an inspection of the table, that as the quantity of water added increases, the sugar obtained per unit of water added rapidly decreases; for example, with canes containing 10% of fibre, the addition of 10% of water corresponds to an increase in the extraction of 6%, and if 30% of water be added the extraction due to the water is 8.4%, an increase of only 2.4% for an addition of 20% of water.

The proportion of sugar extracted due to the dry crushing, and due to saturation, varies in accordance with the fibre in the cane; as the fibre increases, more sugar is left in the dry crushed bagasse, and a greater proportion is obtained, due to the saturated crushing; the admixture of the added water is never complete, and hence with high fibre in cane it becomes of greater importance to carefully oversee the admixture of the added water, and to obtain as efficient a dry crushing as is possible.

#### *Double maceration.*

Instead of applying the water in one dose it may, in a twelve roller mill, be applied in two, a portion after the preliminary dry crushing, and a portion after the saturated bagasse has been crushed in the third mill. The calculation of the extraction with complete admixture and upon the same data as before can be made as follows:

In the case of a cane with 10% of fibre crushed in the preliminary dry crushing to 45% of fibre, and then after the addition of water 10% on the weight of the cane, crushed to 50% of fibre, the total extraction (see Table II) is 95.05%, leaving 4.95% in the bagasse. To this bagasse let water 10% on weight of cane be again added with complete admixture, and let the bagasse saturated for the second time be again crushed to 50% of fibre; then of the sugar remaining  $\frac{wm}{f + wm} \frac{wm}{fm}$  part is obtained in the expressed diluted juice. Substituting for  $w$  .10, for  $m$  .50, and for  $f$  .10, this expression becomes .5. Hence of the 4.95 sugar in

the already partially treated bagasse  $.5 \times 4.95 = 2.475$  is obtained, making the total extraction under these conditions  $95.05 + 2.47 = 97.52$ , compared with the 96.61 obtained under equal conditions, except that the water was added in one dose. In Table III, I have calculated the possible extractions on the supposition that the canes are first crushed to a fibre content of 45% and then twice in succession to a fibre content of 50% ; water 10%, 15%, etc., being applied behind the second and third mills. The results of the calculation showing the extraction due to the added water may be compared with those set out in Table II, which was calculated on the basis that all the water was added in one dose; generally there is indicated an increase in the extraction in favor of double maceration of the order of 1%, and this is, I take it, the benefit to be obtained from a twelve roller mill, as compared with a nine roller mill when the quantity of cane milled remains the same. In a scheme of this sort so complicated a question as the increase in the capacity of the plant due to the installation of an additional mill cannot be expressed on paper.

#### *The return of diluted juices.*

The highest possible efficiency of the added water occurs when the diluted juices from the last mill are used to saturate the bagasse coming from a preceding mill; a complete algebraical expression representing this system of working is not easy to obtain, and when it is obtained it is not elegant. A comparison of working with water only, and with return of diluted juices is best shown by means of a worked out example.

Let the milling plant be a twelve roller mill; the canes are subjected to a dry crushing in the first six rollers until the percentage of fibre is 45%; water 30% on weight of cane is then added behind the *third* mill, and the diluted juices coming from the fourth mill are used to saturate the bagasse coming from the dry crushing; in the third and fourth crushings the bagasse is taken as having 50% of fibre; the cane is assumed to have 12% of fibre, and the same allowance as heretofore is made for the decreased sugar value of the residual juice in the bagasse and complete admixture of the diluents is assumed.

Canes containing 12% of fibre when crushed to 45% of fibre will on the lines already established afford in the expressed juice

85.82% of the sugar originally present, leaving 14.18% in the dry crushed bagasse; to this 14.18 let 30 water per 100 cane be added, and let the saturated bagasse be crushed to 50% of fibre; then applying the formula  $\frac{m' (f + wm) - fm}{m' (f + wm - fm)}$  an extraction of 10.36 per 100 sugar in cane is obtained in this saturated crushing. Let the diluted juice containing this 10.36 sugar be applied to the dry crushed bagasse; the first effect of returning this diluted juice is to reduce the extraction from 85.82% to  $85.82 - 10.36 = 75.46\%$ , leaving 24.54% in the bagasse. If this saturated bagasse be crushed to 50% of fibre, 73.1% of the sugar it contains is obtained;  $.731 \times 24.54 = 17.94$ , so that the extraction at this stage is  $75.46 + 17.94 = 93.40$ , and 6.60% is left in the bagasse as it now leaves the third mill. To this crushed saturated bagasse let 30 water per 100 cane be added, and let it be again crushed to 50% of fibre; then of the sugar present 55.5% is obtained;  $.555 \times 6.60 = 3.66$ , so that the extraction has now reached  $93.40 + 3.66 = 97.06\%$ . Now let the 3.66 sugar contained in diluted juice be applied to the dry crushed bagasse, so that the extraction is reduced to  $85.82 - 3.66 = 82.16$ , there now being 17.84% in the bagasse; as before, 73.1% of this, or 13.04, is extracted in the third mill, making the total extraction at this stage  $82.16 + 13.04 = 95.20$ , and leaving 4.80% in the bagasse; again adding 30 water, 55.5% of this, or 2.66% is obtained in the fourth mill, so that the total extraction now is  $95.20 + 2.66 = 97.86\%$ .

Proceeding in this way, and calculating the successive extractions by a series of steps, it is noticed that each successive addition to the extraction becomes smaller and smaller, until no appreciable difference between any two consecutive extractions is found; in this case the limiting value is found to be practically 98.0%.

Under equal conditions, but with the water applied half after the second and half after the third mill, and no return of diluted juice, the extraction was found to be 97.44.

For the purpose of convenient comparison, I collect here comparative data calculated on the lines followed above:

If the extraction in a nine roller mill with single maceration is ..... 96.18

Then the extraction in a twelve roller mill with the same quantity of water added in two portions is..... 97.44  
 And if all the water be added after the third mill, and the last mill juice be returned behind the second mill, then the extraction is ..... 98.00

I have not included any calculation of divided addition of water, or of return of diluted juices in a nine roller mill, as generally the bagasse coming from the first mill is not sufficiently well crushed to absorb a diluent, so as to obtain any useful effect.

*The effect of an inferior dry crushing.*

Instead of taking 45% of fibre in the dry crushed bagasse, let the percentage of fibre be 40%. Then if the canes contain 12% of fibre, the extraction due to dry crushing is 81.93%, leaving 18.07% in the bagasse; let this bagasse after the addition of water be crushed to 50% of fibre; below I have calculated what will be the extraction with single maceration after the addition of water 10%, 20%, etc., on cane, and for the purpose of comparison add the figures already obtained when the dry crushed bagasse contains 45% of fibre.

	Water added per 100 cane.				
	10	20	30	40	50
40% of fibre in dry crushed bagasse .....	92.26	94.29	95.48	96.26	96.80
45% of fibre in dry crushed bagasse .....	93.10	95.09	96.19	96.89	97.37

The advantage in favor of the more effective dry crushing is in reality greater than is shown in the above calculation; complete admixture is in both cases assumed; in practice we do not obtain complete admixture, but the admixture will be the less imperfect the more the bagasse is disintegrated; that is to say, when the fibre content is higher.



# SUGGESTED METHODS TOWARDS THE CONTROL OF THE MILLING PLANT.

## 1. *The density of the last mill juice.*

On the supposition that the density of the juice is constant throughout the cane (a supposition that is not very far from the truth) it is easy to obtain the density of the last mill juice when complete admixture is assumed. For example, let canes with 12% of fibre be crushed until they contain 45% of fibre; then the weight of juice remaining in the bagasse per unit weight of cane is  $\frac{.12 (1 - .45)}{.45} = .1467$ ; let this juice be of density 18 Brix, and let water 20% on cane be added with complete admixture. Then the density after mixture, i. e., the density of the last mill juice is  $\frac{.1467 \times 18}{.1467 + .2} = 7.61$ .

In Table IV, I have calculated for a single maceration process the density of the last mill juice for degrees Brix, in the normal juice from 15 to 22, and for added water per 100 cane from 10 to 50, the dry crushed bagasse containing 45% of fibre, and the cane containing 12% of fibre. As the mixture becomes less complete, less solids are extracted, and the density of the last mill juice will fall. This table and calculation is introduced as a means of overseeing the efficiency of the added water.

## *Comparison of last mill juice with the residual juice in bagasse.*

A number of years ago it was the custom in Java mills to work out a "Coefficient of admixture of added water" on the following lines:

$$\text{Sugar \% in residual juice in bagasse} = \frac{\text{Sugar per cent. in bagasse}}{1 \text{ fibre per cent. in bagasse}} \times 100.$$

$$\text{Coefficient of admixture} = \frac{\text{Sugar \% in last mill juice}}{\text{Sugar \% in residual juice}}$$

This figure does not appear in the more recent reports, and for this reason I believe that it is no longer employed.

The figure as it stands is liable to misinterpretation; if a small quantity of water has been used a high coefficient must necessarily result, even if no admixture whatever has taken place; and as the residual juice always contains less sugar than that already expressed an accurate comparison on these lines is impossible.

*The relation between added water % on canes and between dilution % on normal juice.*

As the weight of the canes is greater than the weight of the normal juice, it might appear that the figure giving the added water % on canes would be less than that giving the dilution % on normal juice; a great part of the water added does not, however, enter into the mixed juice, but passes away with the bagasse, and with complete admixture the figure expressing the added water % on canes will always be considerably greater than that expressing the dilution % on normal juice. To obtain a comparative table of these figures I proceed as follows: The degree Brix is taken as being uniform throughout the cane; let the degree Brix be 18; let the canes contain 12% of fibre and be dry crushed to 45% of fibre, after which with complete admixture water 20% on cane is added, and the saturated bagasse crushed to 50% of fibre. In a dry crushing following on the equations already established there are obtained 73.33 parts of juice at 18 Brix per 100 cane; 14.67 parts of juice are left in the bagasse, which, when completely mixed with 20 parts of water give 34.67 parts of diluted juice at 7.61 Brix; on crushing this bagasse to 50% of fibre there are obtained 22.67 parts of diluted juice at 7.61 Brix; this, when mixed with 73.33 parts of normal juice at 18 Brix, will give 96 parts of mixed juice at 15.55 Brix, and the dilution % on normal juice is by the usual method of calculation 15.75%; the added water per cent. on cane at the same time being 20%. In Table V, I have calculated for single maceration and complete admixture the dilution %, on normal juice when water 10% to 50% is added to canes containing 12% of fibre and dry crushed to 45% of fibre, and after saturation to 50% of fibre.

Now if the admixture is incomplete water passes into the mixed juice without carrying in the sugar which it was the object of its application to obtain, and the dilution will be higher than calculated above. Such a system of comparison gives, then, an idea of the efficiency of the added water, and may be used in the control or technical oversight of a mill, and it is to this end that the calculation has been introduced.

*A method for expressing the efficiency of the added water.*

A control or oversight of the useful effect of the added water is afforded, as has been shown above, by comparisons of the figures expressing the added water % on canes with the dilution % on normal juice, and also by comparing the density of the last mill juice with the calculated figure when the admixture is complete. A more exact and definite comparison may be obtained by the use of the following methods:

In a plant employing a single maceration process, let the canes contain 12% fibre, and let them be dry crushed to 45% of fibre; then on the lines already established, the extraction due to the dry crushing is 85.82%. Let water 20% on cane be added to the dry crushed bagasse; then with complete admixture and crushing to 50% fibre, a further extraction of 9.20 is obtained; suppose the actually recorded extraction is 93.63%; then that due to the saturation is  $93.63 - 85.82 = 7.81$ . What may be termed the efficiency of the added water is then  $\frac{7.81}{9.20} = 8.49$ ; i. e., the added water has extracted 84.9% of the maximum amount of sugar possible. To apply this formula in actual practice demands a knowledge of the fibre in the dry crushed bagasse, a determination that is not usually made; perhaps in actual work it would be sufficient to determine the average extraction due to the dry crushing process (varied, of course, as the fibre in the cane varies) and to use the figure so determined in the calculation of the efficiency of the added water.

Actually the amount of sugar extracted in the mills in these Islands falls short of that which with complete admixture would be obtained with a single maceration process; I am of the opinion that the calculated figure for the extraction due to saturation in a single maceration process might be made the basis upon which the efficiency of the added water is expressed, independent of what system of maceration is employed.

*The effect of varying quantities of fibre in the material treated.*

The effect of an increase in the fibre content of the canes in decreasing the amount of juice obtained in the dry crushing has been given in a preceding paragraph; with a maceration process some-

what different results are obtained, and a more extended analysis is given.

Let there be taken as types canes containing 10% and 12% of fibre, and let these canes contain the same amount of sugar, and be similar in all respects except in so far as concerns the percentage of fibre; as in previous examples, let these canes be subjected to a dry crushing to 45% of fibre, followed by a crushing to 50% of fibre after the addition of water 20% on weight of cane; complete admixture is assumed, and the same allowance as previously made for the decreased sugar value of the residual juice in the bagasse. The canes with 10% of fibre will give an extraction of 89.01% in the dry crushing, and those with 12% of fibre will yield 85.82%. An extraction of 95% is to be obtained in both cases; the amount of water necessary to be added in saturation to the bagasse can be obtained by solving the equation  $\frac{m'(f + wm) - fm}{m'(f + wm - fm)} = a$ , where  $a$  is the proportion of sugar required to bring the extraction up to 95% expressed as a part of that left in the bagasse after the dry crushing, and  $m, m', f$ , and  $w$  have the significance already attached to them. In the case of the canes containing 10% of fibre the sugar left in the bagasse after the dry crushing is  $100 - 89.01 = 10.99$ ; to bring the extraction up to 95% there must be a further extraction of  $95 - 89.01 = 5.99$ , so that  $a = \frac{5.99}{10.99} = .545$ . Substituting for  $m, m'$ , and  $f$  their proper values,  $w$  is found to be 9.76; i. e., water 9.76% on cane must be used to saturate the dry crushed bagasse. A similar calculation for the canes with 12% of fibre gives the quantity of water in this case as 19.62% on weight of cane.

With the canes containing 10% of fibre and finally crushed so that the bagasse contains 50% of fibre, the weight of the bagasse is 20% of the canes ( $\frac{f}{m} = \frac{10}{50} = .20$ ); the weight of canes and water added is 109.76, so that the weight of mixed juice is  $109.76 - 20 = 89.76$  per 100 cane. A similar calculation for the canes containing 12% of fibre gives the weight of mixed juice as 95.62, and the weight of bagasse as 24 per 100 cane. The amount of sugar in the mixed juices is in both cases the same; let the mixed juice from the canes with 10% of fibre be 16 Brix; then that from the canes with 12% of fibre will be  $16 \times \frac{89.76}{95.62} = 15.0$ .

A comparison of the results to be obtained from the two types of canes stands as below :

Fibre	Weight of mixed juice per 100 cane	Brix of mixed juice	Weight of bagasse per 100 cane	Extraction
10	89.76	16	20	95
12	95.62	15	24	95

In so far as regards the fuel economy I calculate as under. To concentrate 100 parts of juice at 16 Brix to 55 Brix entails an evaporation of 70.90% on the weight of the juice.  $.907 \times 89.76 = 63.64$ , and if this is treated at quadruple effect it is equivalent to the evaporation at single effect of 15.91 water per 100 cane. The whole concentration to massecuite at 95 Brix entails the evaporation of 83.16% of the weight of the mixed juice;  $.8316 \times 89.76 = 74.64$ , so that  $74.64 - 63.64 = 11.00$  is done at single effect in the pans. The whole evaporation referred to single effect will in this case be represented by the figure  $15.91 + 11.00 = 26.91$ . A similar calculation for the canes containing 12% of fibre gives the total evaporation as represented by 28.13. A greater consumption of steam is then required for an equal weight of sugar when the fibre increases, but on the other hand there is a very much greater quantity of bagasse to afford fuel.

The calculation made immediately above supposes ideal conditions, such as are never reached in practice, and may lead to the idea that it is my contention that canes of a high fibre content are more suited for factory work, owing to increased amount of fuel obtained, than those with a lower fibre content. Instead of assuming that the water works at its maximum efficiency, let it only extract half the amount of sugar that it obtained according to the calculation above. The extractions in the two cases now appear :

$$\begin{aligned}
 10\% \text{ fibre ; } & 89.01 + \frac{5.99}{2} = 92.00 \\
 12\% \text{ fibre ; } & 85.82 + \frac{9.18}{2} = 90.41
 \end{aligned}$$

and the result is very different to what was obtained when ideal conditions of working were assumed.

A point of very considerable importance, and upon which this scheme of calculation bears is the trash which in greater or lesser amount accompanies the cane to the mill; in the calculation above it was shown that 2% more fibre in the cane had the effect of practically doubling the amount of water required to bring the extraction up to 95%, and that with imperfect admixture the extraction obtained with the canes with high fibre was even with this quantity of water much lower than that obtained under equal conditions with canes of low fibre.

### *Solar evaporation.*

A problem similar to the above, but leading to a different conclusion, arises in the system of artificially ripening canes by the withholding of the irrigation water for a period of about three months previous to harvest; the result of this practice is, I take for this occasion, merely an evaporation of a part of the water contained in the cane, but little sugar being formed, the solution of that already present being concentrated.

Before the withholding of the irrigation water let there be 100 tons of cane containing 10% of fibre, 14% of solids, and 76% of water; let a process of solar evaporation continue until sufficient water has been removed to raise the fibre to 12%, the absolute weight of all the materials other than the water remaining the same; then the weight of cane will be reduced to 83.33 tons and the percentage of solids will rise to 16.8%. Now let the canes as they exist before and after the ripening process be treated by a single maceration process so as to obtain an extraction of 95%, from calculations similar to those already detailed, the results of the processes will appear as under:

Weight of cane	Fibre % in cane	Weight of mixed juice	Weight of bagasse	Water added	Brix of mixed juice	Extraction
100	10	89.76	20	9.76	14.6	95
83.33	12	79.65	20	16.34	16.5	95

the practical advantage of doing a portion of the evaporation in the field being very pronounced. A further advantage, which is not wrought out in the calculation, is the less weight of cane that has to be cut and transported.

TABLE I.

Showing the extraction per 100 sucrose in cane, calculated from the formula :

Extraction =  $100 \times \frac{m - f}{m (1 - f)}$  ; results being increased 3% to allow for decreased sugar value of residual juices ; bagasse containing 45% of fibre.

Fibre in Cane.	Extraction.
10.	89.01
10.5	88.23
11.	87.42
11.5	86.64
12.	85.82
12.5	85.00
13.	84.17
13.5	83.34
14.	82.50

TABLE II.

Showing the maximum extraction to be obtained with single maceration, with complete admixture of added water ; dry crushed bagasse containing 45% fibre, and saturated crushed bagasse containing 50% fibre.

Extraction due to saturation in upper, and total extraction in lower, line.

L'ibre per 100 cane	Water added per 100 cane.									
	10	15	20	25	30	35	40	45	50	
10.	6.04	6.95	7.58	8.04	8.39	8.66	8.88	9.07	9.22	
	95.05	95.96	96.59	97.05	97.40	97.67	97.89	98.08	98.23	
10.5	6.36	7.33	8.00	8.50	8.88	9.18	9.41	9.61	9.80	
	94.59	95.56	96.23	96.73	97.11	97.41	97.64	97.84	98.03	
11.	6.68	7.71	8.44	8.98	9.39	9.72	9.99	10.21	10.40	
	94.10	95.13	95.86	96.40	96.81	97.14	97.41	97.63	97.80	
11.5	6.97	8.07	8.85	9.43	9.87	10.23	10.51	10.76	10.96	
	93.61	94.71	95.49	96.07	96.51	96.87	97.15	97.40	97.60	
12.	7.28	8.44	9.27	9.89	10.37	10.75	11.07	11.33	11.55	
	93.10	94.26	95.09	95.71	96.19	96.57	96.89	97.15	97.37	
12.5	7.58	8.81	9.68	10.34	10.86	11.27	11.61	11.89	12.13	
	92.58	93.81	94.68	95.34	95.86	96.27	96.61	96.89	97.13	
13.	7.87	9.17	10.09	10.80	11.35	11.70	12.15	12.45	12.71	
	92.04	93.34	94.26	94.97	95.52	95.96	96.32	96.62	96.88	
13.5	8.17	9.52	10.50	11.24	11.82	12.29	12.68	13.00	13.27	
	91.51	92.86	93.84	94.58	95.16	95.63	96.02	96.34	96.61	
14.	8.46	9.87	10.90	11.68	12.30	12.80	13.21	13.55	13.85	
	90.96	92.37	93.40	94.18	94.80	95.30	95.71	96.05	96.35	



TABLE III.

Showing the maximum extraction to be obtained with double maceration with complete admixture of added water; dry crushed bagasse containing 45% fibre and saturated crushed bagasse containing 50% fibre.

Extraction due to saturation in upper, and total extraction in lower, line.

Fibre per 100 cane	Water added per 100 cane.			
	20	30	40	50
10.	8.51	9.37	9.85	10.15
	97.52	98.38	98.86	99.16
10.5	9.00	9.94	10.47	10.80
	97.23	98.17	98.70	99.03
11.	9.49	10.52	11.11	11.48
	96.91	97.94	98.53	98.90
11.5	9.94	11.06	11.71	12.12
	96.58	97.70	98.35	98.76
12.	10.42	11.63	12.34	12.79
	96.24	97.45	98.16	98.61
12.5	10.88	12.19	12.95	13.45
	95.88	97.19	97.95	98.45
13.	11.33	12.74	13.57	14.11
	95.50	96.91	97.74	98.28
13.5	11.78	13.28	14.18	14.66
	95.12	96.62	97.52	98.00
14.	12.23	13.82	14.78	15.41
	94.73	96.32	97.28	97.91

TABLE IV.

Giving the density of last mill juice in a single maceration process with complete admixture; the dry crushed bagasse containing 45% of fibre, and cane containing 12% of fibre.

Degree Brix of Normal juice.	Water added per 100 cane.									
	10	15	20	25	30	35	40	45	50	
15	8.92	7.42	6.35	5.54	4.92	4.43	4.02	3.69	3.40	
16	9.51	7.91	6.77	5.92	5.25	4.72	4.29	3.93	3.63	
17	10.11	8.41	7.19	6.28	5.58	5.02	4.56	4.18	3.86	
18	10.70	8.90	7.61	6.66	5.91	5.32	4.83	4.43	4.08	
19	11.30	9.39	8.04	7.03	6.24	5.61	5.10	4.67	4.31	
20	11.89	9.89	8.46	7.40	6.57	5.91	5.37	4.92	4.54	
21	12.49	10.38	8.88	7.76	6.90	6.20	5.63	5.16	4.76	
22	13.08	10.88	9.31	8.13	7.22	6.49	5.90	5.41	4.99	

TABLE V.

Giving, for a single maceration process, the density of mixed juice and dilution per cent. on normal juice for canes containing 12% fibre, dry crushed bagasse containing 45% fibre, and saturated crushed bagasse 50% fibre, and normal juice containing 18% of solids.

Added water % on cane.	Density mixed juice.	Dilution % on normal juice
10	16.92	6.38
15	16.23	10.90
20	15.55	15.75
25	14.89	20.88
30	14.27	26.14
35	13.69	31.49
40	13.15	36.88
45	12.65	42.29
50	12.18	47.78









**DIVISION OF AGRICULTURE AND CHEMISTRY**

**BULLETIN NO. 23**

**REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION**

**Use of Formaldehyde Solution  
In Sugar Mills**

**BY R. S. NORRIS**

**HONOLULU, T. H.  
FEBRUARY 19, 1908**



# HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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**REPORT OF WORK  
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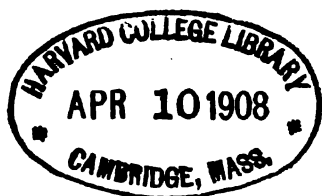
**Use of Formaldehyde Solution  
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**BY R. S. NORRIS**

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**HONOLULU, T. H.  
FEBRUARY 19, 1908**



*His Honor*

## LETTER OF TRANSMITTAL.

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To the Experiment Station Committee of the Hawaiian Sugar  
Planters' Association, Honolulu, T. H.

Dear Sirs:—I, herewith, submit for publication as Bulletin  
No. 24 of the Division of Agriculture and Chemistry an article  
entitled: "The Deterioration of Sugars on Storage." This  
article has been prepared by Mr. Noël Deerr and Dr. R. S.  
Norris.

Yours very truly,

C. F. ECKART,

Director, Division of Agriculture and Chemistry.

Honolulu, Hawaii, February 7th, 1908.



## THE DETERIORATION OF SUGARS ON STORAGE.

By Noël Deerr and R. S. Norris.

The question of the deterioration of sugars on storage is one that has been much studied in both the cane and beet sugar industry. Since sugars here are often stored over lengthy periods, and also are frequently as much as 130 days in transit round the Horn to New York, this subject is one of peculiar interest to the industry in these islands.

To obtain information on the causes of deterioration the matter has been studied at the Station, and the results of the investigation are included in the present Bulletin.

The scheme of work outlined at the inception of the investigation was as follows:

A number of sugars of known origin were to be obtained and analyzed on receipt; the analysis was to be repeated after intervals of two months and four months; from the analysis we hoped to obtain information correlating the composition of sugars with their keeping qualities. At the same time determinations of the number of organisms in the sugars examined were made.

To this end the following letter was addressed to all the plantations subscribing to this Association:

"It is the object of the Division of Agriculture and Chemistry to take up the question of the causes tending towards a deterioration of sugar on storage. The Station will be much obliged if you will let us have average samples of about one-half pound each of sugars, both first product and second product in case two classes are shipped. Would you also supply the following information on the following points:

- "1. The degree of alkalinity to which juices are limed.
- "2. Is the sugar washed in the centrifugals, and if so, the source of the water?
- "3. Is the sugar dried?

"Any further information bearing on the subject that you can give will be much appreciated."

In all we received replies from 29 factories, covering 45 samples of sugar.

Practically all these sugars were made from juices lined to neutrality, or to slight alkalinity.

Thirteen of the sugars were washed with water in the centrifugals, not including four sugars where it was stated enough water was used to wash down the spindles.

Seven of the sugars had been passed through a Hersey drier.

The determinations made on the sugars were,—

Polarization.

Sucrose (Clerget) %

Glucose %

Moisture %

Ash %

Chlorine %

Number of organisms per gram.

Acidity.

*Previous work.*

Cl'aassen<sup>1</sup> states:

"It is also a requisite of good raw sugar that it does not undergo change in storage. This is the case when the sugar shows an alkaline reaction with phenolphthalein, and when it is free from the germs that cause sugar to invert, and also free from easily decomposable non-sugars."

He also states that a raw sugar with an adhering layer of supersaturated molasses keeps well if the layer remains supersaturated, as in this case bacteria cannot develop; if the sugar is kept in places where moisture can be absorbed there is danger of deterioration.

To sugars manufactured with sulphurous acid he ascribes enhanced keeping qualities, due to the antiseptic properties of this substance. He calls attention to the danger of bagging sugar while still warm, ascribing the deterioration then observed to the oxidization of organic non-sugars.

Strohmer<sup>2</sup> found alkaline sugars kept longest, and recommends an alkalinity in the sugar of not less than .033% lime.

Von Lippmann<sup>3</sup> also finds that sugars alkaline to phenolphthalein undergo no change. On the other hand, Herzfeld<sup>4</sup> states that alkalinity is no criterion of the keeping qualities of sugar, and Koydl<sup>5</sup> claims that an excessive alkalinity increases the rate at which sugars deteriorate, and suggests that this is due to the action of lime on reducing sugars.

Pekalharing<sup>6</sup> shows that the inversion of sugars on storage is not due to the salts contained in the sugars, and suggests the deterioration is due to organisms introduced with the bags.

Grieg Smith<sup>7</sup> has studied the subject in Australia from a bacteriological standpoint, and ascribes the deterioration of sugars to a specific organism which he has named *Bacillus leraniformans*. He found this organism constantly associated with deteriorated sugars, and also in raw cane juice. The organism was also found in sugars from Demerara, Mauritius, Peru, Egypt, Java, Germany, Russia, France, Fiji, so that it has a truly cosmopolitan distribution. He gives the optimum temperature for its growth as 37° C. (96.6° F.), and concludes—"In view of this faculty of growing in poor media, and of the fact that an inversion of sugar accompanies the growth, there can be no doubt that it is alone responsible for the inversion of crystals in bulk, and that the chief condition for its growth is a more or less moist state of the sugar, and a warm temperature."

Shorey<sup>8</sup> states that alkalinity of sugars is not a cause of their keeping, and that high moisture is not a cause of their deterioration; he attributes inversion to the presence of the organism *Penecillium glaucum*, and believes that it is drawn into the sugars along with the current of air in the centrifugals. He recommends that in the curing of sugars dry steam be admitted to the baskets. Grieg Smith<sup>7</sup> objects to the conclusion of Shorey that the inversion of the sugars was not caused by bacteria, because he (Shorey) made no search for bacteria, and "his remarks about the Hawaiian sugars would apply equally to these Australian samples," which were known to contain inverting bacteria.

Watts<sup>9</sup> calls attention to a rise in the polarization of muscovado sugars on storage, followed by a fall in the polarization, and in a subsequent paper<sup>10</sup> in connection with Tempany attributes the rise to the selective action of certain organisms for the levulose present, the subsequent fall becoming apparent when the destruction of the dextrose and cane sugar begins.

The question of deterioration of sugars was very prominent in these Islands in 1897.



Dr. Maxwell<sup>11</sup> the then Director of this Station, attributed the deterioration to fermentation, and laid great stress on the necessity of working with very alkaline juices and obtaining alkaline products, and traced a greater deterioration when low sugars were returned than when "*straight*" first sugars were made. The source of infection he thought was the vessel containing the low grade massecuite. Shorey was at issue with Dr. Maxwell on many points, especially with regard to the return of low sugars and alkalinity. He also regarded fermentation as the cause of this deterioration, but considered the centrifugals the source of infection, the organism affecting the change being drawn into the sugar along with a current of air; he obtained good results by steaming the sugars in the baskets, and laid great stress on the necessity of shipping dry sugars.

Mr. J. N. S. Williams at the last meeting (1907) of the Planters' Association, called attention to the "sweating of sugars," i. e., to the absorption and exudation of moisture by stored sugars, and was inclined to attribute this behaviour to climatic influences, and to the position of the warehouses.

In the pages that follow, these points and others are discussed in connection with the analyses that we have made.

For easy reference the polarization of the sugars as received and at intervals of two months and four months are brought together below in Table I; those sugars which retained their polarization being separated from those which did not. In this table is also included the results of the determination of the moisture in the different sugars, and of the determination of the number of micro-organisms found.

TABLE I.

Reference No.	Moisture .....	Initial Polarization .....	Polarization after 60 days .....	Polarization after 120 days .....	Initial % Sucrose (Clerget) .....	% Sucrose (Clerget) after 60 days .....	% Sucrose (Clerget) after 120 days .....	Initial Number of organisms per gram .....	Number of organisms per gram after 60 days .....	Number of organisms per gram after 120 days .....
21	1.04	96.7	95.8	95.1	97.0	96.3	95.4	148	2000	408
13 AA	.92	97.8	96.8	96.7	98.0	96.6	95.8	136	8	8
13 A	1.52	95.8	92.6	92.2	96.1	93.2	93.1	87	8	88
2 A	1.41	96.4	94.6	92.5	96.5	94.4	92.9	68	172	88
2 B	1.66	94.5	94.6	91.4	94.4	.....	92.3	12	68	96
24 A	.80	97.9	97.0	95.5	98.3	96.7	95.6	3000	8	8
19	1.50	95.8	94.5	93.0	96.3	94.8	93.6	56	8	8
12 First	1.68	95.2	93.9	92.7	95.7	93.8	92.8	1000	8	8
23 A	2.25	95.0	94.9	89.0	95.2	95.0	90.0	136	144	56
23 B	2.42	92.8	90.3	91.6	93.0	91.0	92.0	5000	8	8
37 First	1.52	96.9	95.4	95.2	97.0	95.3	95.6	4000	8	8
37 Second	1.66	95.5	95.0	.....	96.0	95.1	.....	4000	8	8
33 A	1.04	97.0	97.0	96.4	97.1	97.1	96.6	2000	8	8
7 AA	1.44	95.4	95.6	92.9	95.7	.....	93.0	2400	8	8
Average	1.49	.....	.....	.....	.....	.....	.....	.....	.....	.....
41 A	.75	97.4	97.3	97.3	97.6	.....	97.4	12	32	24
41 B	1.54	94.4	94.2	95.0	95.0	.....	95.0	56	360	112
27 A	.85	96.8	97.2	97.2	97.2	.....	97.0	40	60	100
27 B	2.34	92.4	92.0	92.6	92.6	.....	93.2	27	50	256
9	.69	96.7	96.8	97.1	97.0	.....	97.2	4	20	16
34	1.23	96.2	96.4	97.0	97.0	.....	95.9	40	40	40
4	.41	98.2	98.4	98.4	98.4	.....	98.6	216	440	152
3 A	1.29	95.3	95.6	95.4	95.9	.....	96.0	44	230	54
3 B	2.08	93.7	95.0	95.2	94.5	.....	94.7	28	420	8
36 A	.69	97.4	97.1	97.1	97.1	96.9	96.6	2000	2000	2000
36 B	.51	96.5	96.4	96.8	96.8	96.7	96.0	10000	10000	3000
39 A	.55	97.5	97.8	97.8	97.7	97.6	97.8	244	100	152
39 B	.73	96.5	96.6	97.2	96.9	96.8	96.4	848	.....	760
43	1.25	96.4	96.6	97.2	96.5	96.6	97.1	40	32	76
30	.92	96.5	96.8	96.5	96.7	96.8	96.8	220	24	148
16 Syrup	.56	97.4	97.8	98.2	97.7	97.8	98.3	72	80	24
16 Syrup & Molasses	.63	96.8	96.9	97.4	97.0	97.0	97.6	176	180	68
20	1.01	97.2	96.8	96.8	97.3	.....	97.3	46	48	28
6	.70	97.3	97.2	97.2	97.7	.....	97.1	16	98	88
5 A	.77	97.3	97.1	97.3	97.5	97.4	97.9	24	252	224
5 B	.83	95.9	95.8	95.9	96.2	.....	96.1	16	352	96
7 A	.62	97.5	97.8	97.8	98.1	.....	97.9	508	1440	2000
45	.61	97.1	97.3	97.6	97.5	96.9	97.9	1236	1560	.....
25	1.36	95.2	95.8	95.3	95.7	95.9	95.6	200	224	96
1	1.43	94.1	94.0	94.8	96.1	95.9	94.7	316	144	176
33 AD	1.31	95.8	95.2	95.6	95.8	.....	95.8	124	120	76
12 Washed	1.25	95.8	95.2	95.8	95.9	94.3	95.7	4000	320	60
Average	1.02	.....	.....	.....	.....	.....	.....	.....	.....	.....

*Connection between moisture in sugars and keeping qualities.*

Referring to the tabulated results a connection between moisture and keeping qualities of the sugars is evident.

The average percentage of moisture in the sugars which deteriorated is 1.49, and in those which retained their polarization is 1.02; this result points to the advisability of reducing the moisture to as low a figure as is possible; at the same time, a low content of moisture in a sugar does not always mean that the sugar will retain its polarization on keeping, as amongst the sugars that have deteriorated are two, 13 AA and 24 A, which have less than 1% of moisture, but notwithstanding it is evident that a connection between deterioration and high moisture does exist. The value of a low content of moisture, in this instance obtained by drying the sugars in a Hersey drier, is illustrated in a very vivid manner in the sugars 36 A and 36 B. These sugars had a very low percentage of water, .69% and .51% respectively, and contained at the same time a relatively enormous number of organisms, which, owing to the dryness of the sugars were unable to develop and thus cause a fall in polarization. These sugars came from a factory which had at one time great trouble with deterioration, which after the installation of a drier disappeared. When these sugars were allowed to become wet by standing in a moist atmosphere a very rapid fall in polarization was observed.

*Acidity.*

None of the sugars that we examined were alkaline, but all as determined by the use of phenolphthalein showed an acid reaction. The method of determining the acidity was as follows :

Five grams of the sugar were dissolved in 50 c. c. of water, and titrated with a 1-10 normal solution of standard alkali until a distinct red coloration was given by phenolphthalein. Owing to the coloring matter present in the sugars the determination can lay no great claims to extreme accuracy. Below in Table II are given the results, the sugars being divided into those that retained and those that did not retain their polarization. The figures expressing the acidity are the number of cubic centimeters of tenth-normal alkali required to neutralize the acid in the 5 grams of sugar. On inspection it will be seen that no connection between the acidity of the sugars and their keeping qualities is to be found.

TABLE II.

SUGARS WHICH DETERIORATED		SUGARS WHICH RETAINED THEIR POLARIZATION	
Reference No.	Acidity	Reference Number	Acidity
13 A	.7	20	.5
13 AA	.3	6	.3
2 A	.6	17	.3
2 B	.8	5A	.4
21	.3	5B	.4
24 A	.5	7 A	.4
19	.5	12 Washed	.3
12 First	.4	36 A	.4
23 A	.5	36 B	.5
23 B	1.2	39 A	.5
37 A	.5	39 B	.4
37 B	.9	43	.3
33 A	.7	30	.5
7 AA	.6	15 Syrup	.2
Average	.59	16 Syrup and Molasses	.2
		45	.4
		25	.4
		1	.9
		33 AD	1.2
		41 A	.9
		41 B	1.1
		27 A	.4
		27 B	1.6
		9	.4
		34	.7
		4	.1
		1	.8
		Average	.57

*Bacteriological examination of the sugars.*

At the inception of this study the following scheme was mapped out: A count was to be made of the number of organisms in each sugar as it arrived, at an interval of two months, and again at an interval of four months, at the same time polarizations of the sugars were to be made, and it was in this way hoped to correlate a large number of organisms with a fall in the polarization of the sugars.

The method used to obtain the number of organisms in a sugar was as follows: A quantity of the sugar (we found that .25 gram was a convenient amount) was weighed out onto a square of sterile paper, and transferred to a tube of sterile nutrient agar, the temperature of which was from  $45^{\circ}$  to  $50^{\circ}$  C; the sugar was allowed to dissolve, and after solution the contents of the tube poured into a sterile Petrie dish, the usual precautions to prevent accidental contamination being scrupulously followed. At first organisms in these plates were allowed to develop at room temperature, and later, as the weather became colder, in an incubator at  $30^{\circ}$  C. After 48 hours the number of organisms which developed into colonies were counted; the results of this test are set out in the annexed table, which also included the polarizations of the sugars at the same time. The nutrient medium we used in these determinations was that recommended by Grieg Smith, and was of composition—Agar Agar 1.5%, Sugar 10%, Potassium chloride .5%, Sodium Phosphate .2%, Peptone .1%.

In making determinations in duplicate it was found that agreement between any two was not as close as could be wished; for example, in duplicate experiments we might find the number of organisms per gram varying from 20 to 50, and no great reliance must be placed on the numbers actually entered up; we have entered the numbers up as we found them, where duplicates were made entering up the mean of the observations; actually in work of this sort we think expressions as between 100 and 200 is as close a determination as the conditions of the experiment allows.

In carrying on this work we received much advice and assistance from Mr. L. Lewton-Brain, Director of the Division of Pathology and Physiology of this Station.

#### *Varieties of organisms found.*

The colonies in each plate culture made were subjected to a microscopical examination, and a preliminary classification of the organisms made. Five organisms capable of differentiation by microscopical examination were of frequent occurrence:

1. Rods with terminal spores associated with a surface amoeboid growth on the agar plates.

2. A pear shaped organism exceedingly granular, associated with raised, smooth and slimy colonies.

3. A short thick spore forming rod generally occurring in pairs, and less frequently in chains up to seven, the refractive spore causing the pair of organisms to simulate the appearance of an organism with two spores.

4. A very small rod shaped organism only distinctly visible with very careful focusing, associated with a smooth raised growth on the agar plates.

5. Yeasts.

It is intended to carry on the further study of these organisms in pure culture.

For the present we may say with reserve that we have not positively identified any of the organisms found with the *Bacillus lerniformans* of Grieg Smith.

#### *Connection between deterioration of sugars and bacterial activity.*

In Table I are given results of the polarizations at different periods, and of the counts of the number of organisms present.

The first fourteen sugars entered up are those which have fallen in polarization. In these fourteen are ten where the number of organisms has increased to infinity, and in these the deterioration of the sugars may properly be attributed to the activity of the organisms present. In No. 21, the organisms increased at the end of the second month to 2000, after which they decreased in number. In three instances in which the sugars deteriorated markedly, there was no increase in the number of organisms to account for the fall in the polarization. These sugars are 2 A, 2 B, and 23 A. The sugar 23 A was most carefully examined, and plates of nutrient agar infected with this sugar were inoculated at temperatures 30°C, 35°C and 38°C, all the determinations leading to the same result.

Of the sugars where deterioration might reasonably be ascribed to bacterial activity the organism most frequently occurring was the one we have referred to above as No. 1, which occurred alone or in combination with the other forms in eleven of the sugars which have deteriorated; the other organism of most frequent occurrence was the form which we have temporarily designated No. 2. Amongst the sugars which have not

deteriorated we particularly call attention to 36 A, 36 B and 39 B, notable for the large number of organisms present. These sugars did not deteriorate, and this we think attributable to the low water content of the material, and illustrates the benefits to be obtained by producing a dry article.

Actually we think the results of these determinations allow us to say:

1. That generally deterioration of sugars can be connected with bacterial activity.
2. That, however, cases occur when sugars deteriorate excessively and in which the deterioration can *not* be attributed to bacterial activity as illustrated by the sugars 2 A, 2 B, and 23 A.
3. That sugars containing a large number of organisms retain their polarization provided they contain but little water.

#### *Effect of sterilization on sugars.*

To demonstrate the deteriorating action of micro-organisms on sugars when kept in unfavorable conditions, the following experiment was performed:

A quantity of sugar was filled into wide mouthed Erlenmeyer flasks, and to this was added, drop by drop, so as to obtain a uniform distribution, a solution of the sugar 24 B, which we knew to be infected with micro-organisms. Three of these flasks were then submitted to fractional sterilization at 100° C. for a period of 20 minutes on three successive days. A fourth flask received no sterilization. These flasks, all plugged with cotton wool, were then placed over a flat dish containing water, and covered with a bell jar; a fifth flask, containing unsterilized, infected sugar was placed in a similar position, the water being replaced by a 40% solution of formaldehyde.

The polarization of these sugars was taken at the beginning of the experiment, and after the expiration of 45 days. The following results were obtained, the polarization being referred to dry weight. The amount of water absorbed by the different sugars averaged about five per cent.

	Initial Polarization	After 45 Days
Sterilized sugar.....	97.6	97.2
“ “ .....	97.5	97.2
“ “ .....	97.6	97.2
Not Sterilized.....	97.6	95.6
Not Sterilized, over formaldehyde .....	96.2	96.2

A very large fall in the polarization of the infected and not sterilized sugar is noted, and a smaller one in the sugars that had been sterilized, the sugar in the presence of formaldehyde remaining stationery.

These sugars were inoculated into nutrient agar when it was found that the sterilization had not been sufficient to destroy the organisms originally present; in these sugars there were found after 45 days about 300 organisms per gram; in the unsterilized sugar a very large number; the sugar exposed to formaldehyde being quite sterile.

*Determination of the amount of water at which deterioration begins.*

In order to determine the percentage of water which it is safe to leave in sugars, the following experiment was made:

A good quality of raw sugar was infected with a small quantity of the sugar 24 B, which we knew contained large quantities of organisms which we had connected with deteriorations. The infected sugar was allowed to become very moist, and portions of it, after thorough and complete mixing were partially dried in vacuo over sulphuric acid, so that there was obtain a series of sugars of the same quality, with the moisture increasing in steps from .29% to 1.86%. These sugars were placed in tightly closed bottles and allowed to stand for a month.

This experiment was performed during the winter months, and an incubator not being at first available, the temperature in the box containing the sugars was maintained at night by means of a 4 c. p. incandescent lamp; the temperature varied between 25° C. and 32° C.

The sugars were kept for a second month in an incubator at a temperature of 35° C.

The following results were obtained:



Per cent Water in Sugars	Initial Polarization	Polarization after one month	Polarization after two months
.29	96.8	96.7	96.7
.40	96.6	96.6	96.6
.47	96.8	96.6	96.6
.59	96.8	96.6	96.7
.65	96.4	96.4	96.6
.74	96.4	96.4	96.5
.96	96.1	96.0	96.0
1.04	96.0	95.9	95.7
1.18	96.0	95.2	95.2
1.28	95.8	95.0	95.0
1.36	95.8	95.0	94.7
1.51	95.5	94.7	94.5
1.67	95.6	94.2	94.1
1.80	95.3	93.8	94.0
1.86	96.15	94.4	94.0

The polarizations were made on half normal weights of the sugars, and we do not therefore consider slight differences in the polarizations as indicative of any change in the sugars.

A distinct fall in polarization is observed when the water present has reached 1.04%. In the sugars which we examined from various plantations fourteen were found to deteriorate on keeping; two of these sugars contained less than 1.04% of moisture. Of the sugars that retained their polarization eleven contained more than 1.04% of moisture, seventeen contained less. The correspondence between this experiment and the actual experience with the sugars is, we think, satisfactory, and as a result we think we are justified in suggestion 1% of water as the maximum allowable limit in raw sugars if they are to be stored any length of time. We do not of course say that all sugars containing not more than 1% of moisture will keep, as two of our sugars, 13 A and 24 A, deteriorated, both of which contained less than 1% of water; nor, on the other hand, do we say that a sugar containing more than 1% of water will deteriorate; all we say on the point is that a sugar containing more than 1% of moisture, in the presence of organisms will probably deteriorate, and that a sugar containing less than 1% of moisture will in all probability retain its polarization.

### *Action of the Hersey Drier.*

In the use of the Hersey drier the sugar is raised to an elevated temperature, and we thought it advisable to investigate the action of this elevation of the temperature on the bacterial content of sugars.

We were informed by Mr. C. B. Wells, of Wailuku that in the Hersey drier there used the sugar remains in the apparatus for from 5 to 7 minutes, and that the temperature varies from 130° F. to 160° F.

At Niulii, Mr. Robert Hall informs us sugar stays in the Hersey drier 16 minutes, and reaches a temperature of 125° F.

Three sugars were exposed in a thin layer to a temperature of 80° C. (176° F.) for ten minutes, thus exaggerating the effect of the Hersey drier. Inoculation experiments in the way already described were then made.

	No. of Organisms per gram dried	No. of Organisms per gram not dried
1	42	32
2	25	22
3	35	34

It is thus seen that the action of the Hersey drier has no effect whatever on decreasing the number of organisms present, and its useful effect is to be attributed to the reduction of moisture in the sugars to such an extent that the micro-organisms to which the deterioration of sugars may be attributed cannot develop. Amongst the sugars that we examined were seven that had passed through a Hersey drier. The percentage of moisture, the number of organisms per gram and the behaviour of the sugars on keeping are set out below.

	Water %	NO. OF ORGANISMS			
		Initially	Two Months	Four Months	
5A	.77	24	252	224	Did not deteriorate
5B	.83	16	352	96	" "
36A	.69	2000	2000	2000	" "
36B	.51	11000	10000	3000	" "
39A	.55	44	100	152	" "
2B	1.66	12	68	96	Deteriorated

*Connection between washed sugars and deterioration.*

The majority of the sugars examined were cured without the use of water in the centrifugals. The following were washed with water in the centrifugals:

- 5 A Mixed condensed and well water.
- 5 B Mixed condensed and well water.
- 39 B Flume water.
- 2 B
- 36 A Rain or distilled water.
- 36 B Rain or distilled water.
- 24 A Stored rain water.
- 43 Artesian water.
- 19 Enough water from flume to wipe down spindles.
- 7 A Wet rag to wipe down spindles.
- 7 B Wet rag to wipe down spindles.
- 27 B Wet rag to wipe down spindles.
- 13 A Artesian water.
- 13 AA Very little or none.
- 12 First Pump water.
- 12 Washed Pump water.
- 37 B Gulch water.

Of these sugars nine are included amongst those which lost in polarization, and this leads to a conclusion that a connection exists between the water used in washing sugars and their tendency to lose in polarization; amongst the washed sugars which retained their polarization are five which in addition to washing were passed through the Hersey drier, and were thus brought into a condition suitable for long keeping. It is notable that in three of these sugars which retained their polarization, —36 A, 36 B, and 39 A, a very large number of organisms were found, and we suggest that these organisms had been introduced along with the water used to wash the sugars, the damage to the sugars not being developed owing to the subsequent drying.

Washing of sugars may also be regarded as affording a tendency towards a loss of polarization in that owing to the dilution of the molasses attached to the crystals a more favorable medium is afforded for the growth of micro-organisms than is the case if the film of molasses be more dense; this point has been referred to in the references already quoted.

*Sweating of Sugars.*

Independently of any question of bacterial deterioration of sugars, Mr. J. N. S. Williams at the last (1907) meeting of the Planters' Association called attention to the "sweating" of sugars, i. e., to the absorption and exudation of moisture by stored sugars. Mr. Williams was inclined to attribute this behaviour very largely to climatic conditions and to the positions of the warehouses.

*Amount of moisture absorbed by different sugars.*

We thought it would be advisable to actually determine the amount of water that the sugars we had under examination would absorb when exposed to the atmosphere under exactly equal conditions. The determination was made as follows:

About two grams of the sugars were placed in a thin layer and dried to constant weight at  $100^{\circ}$  C.; the dishes and their contents were then exposed to the atmosphere in a manner so as to be protected from the visits of ants and other insects; after 24 hours the dishes and their contents were again weighed. In Table III below, are collected the amounts of water absorbed in 24 hours expressed as percentages on the dry sugars.

TABLE III.

Reference No.	Low Chlorine Chlorine % on Sugar	Moisture absorbed on exposure to atmosphere for 24 hours	Reference No.	High Chlorine Chlorine % on Sugar	Moisture absorbed on exposure to atmosphere for 24 hours
13A	trace	1.27	17	.006	1.34
13AA	"	1.13	2A	.01	2.62
20	.002	.85	2B	.022	1.75
6	.002	.67	5A	.01	1.03
21	.002	.95	5B	.008	1.13
7A	.002	.49	12 first	.006	2.16
7AA	.004	1.48	23A	.034	1.67
33A	trace	1.12	23B	.162	2.91
33AD	.002	1.13	39A	.012	.79
24A	trace	.95	39B	.020	1.08
9	"	.22	43	.01	.99
3A	"	1.41	41B	.040	1.44
3B	"	1.08	27A	.022	1.16
12 Washed	"	1.77	27B	.078	2.03
36A	"	.34	25	.028	1.51
36B	.002	.99	1	.076	1.38
37A	trace	1.39	Average		1.56
37B	"	1.12			
30	.004	.73			
16 Syrup	trace	.18			
16 Syrup & molasses	.004	.47			
45	trace	.37			
41A	.004	.80			
34	trace	1.08			
19	.002	2.03			
4	trace	.22			
Average		.91			

*Size of grain as influencing absorption of moisture.*

The absorption of moisture by any substance is essentially a contact reaction, and is connected with the area of the substance exposed.

The same weight of a sugar of small grain exposes a larger area than does that of a sugar of large grain, and will hence absorb moisture more quickly, and will retain a larger amount.

In addition, owing to the larger exposed area a small grained sugar will have attached to its surface a greater quantity of molasses than a large grained sugar, and it is to the impurities

or to the molasses that the hygroscopic character of a sugar is to be attributed.

To test this point experimentally two sugars were separated into three portions,—that retained by a 2 millimeter mesh, that passing a 2 millimeter mesh and retained by a 1 millimeter mesh, and that passing a 1 millimeter and retained by a .5 millimeter mesh. These different portions were dried to constant weight, and then exposed to the atmosphere under exactly equal conditions. The annexed table gives the percentages of water absorbed by the different portions.

	Retained by 2 m.m. mesh	Retained by 1 m.m. mesh	Retained by .5 m.m. mesh
A	.90	1.18	1.31
B	1.15	1.20	1.46

*Connection between the non-sugar and moisture absorbed.*

A raw cane sugar consists of cane sugar, dextrose and levulose (these last two being grouped together under the term glucose), organic and inorganic salts of lime, potash and magnesia, and various organic non-sugars. The organic acids which have been isolated from molasses and are consequently present in raw sugars are glucinic, malic, lactic, saccharic, and succinic; in addition, wherever disease attacked canes are being worked up, acetic acid will always be present. The inorganic salts present are chiefly sulphates, phosphates and chlorides.

Of the non-sugars, dextrose is the material present in largest amount and this substance when pure is not hygroscopic; levulose, included with dextrose in the term glucose, was found to absorb 37.52% of its weight when exposed for 24 hours to the atmosphere.

Of the other bodies which may be present the following are known to be hygroscopic:

Calcium chloride, calcium acetate, calcium glucinate, potassium acetate, potassium glucinate.

The glucinates are formed by the action of alkalis on dextrose and on levulose, and in this way glucose may be regarded as a body tending to give a hygroscopic product. This point was put to the test in the following experiment.

To 100 c. c. of a half per cent. solution of dextrose and of levulose were added 1 c. c., 2 c. c. . . . 5 c. c. of a saturated solution of lime. The lime solution contained 0.12 grams lime per 100 c. c. These solutions were evaporated to dryness and then exposed to the atmosphere for 24 hours; in all cases there was obtained a brown colored residue. The percentage increases in weight were found to be:

	1 C. C. Lime Water	2 C. C. Lime Water	3 C. C. Lime Water	4 C. C. Lime Water	5 C. C. Lime Water
Dextrose.....	22.5	20.6	21.3	21.7	23.0
Levulose .....	16.1	18.0	16.3	18.3	17.3

The decomposition products formed by the action of lime on dextrose are evidently very hygroscopic, and indicate the danger of obtaining a hygroscopic product liable to sweat, with juices containing a high content of reducing sugars. It is of interest to note, and a result not expected that increasing the amount of lime does not lead to an increased absorption of water, and that levulose treated in this way absorbs less water than does dextrose, and less than it does without the treatment with lime water.

The difference in the amount of moisture absorbed by the samples was probably due to a slight difference in the surface exposed in each case.

*Connection between chlorine in ash and amount of water absorbed.*

In Wray's Practical Sugar Planter, published in 1849, appears the following remark:

"Saline matter, present in cane juice, depends very much on the soil on which the canes are grown; as, for instance, in the low alluvial lands of Demerara, Louisiana, the Sunderbunds (below Calcutta), and Province Wellesley, canes often imbibe so much saline matter from the soil, that the sugar made from them may be said to be in a constant state of deliquescence."

We determined the chlorine in the ash of all the sugars examined, and this quantity, as a percentage on the sugar itself is entered up in Table III giving the amount of water absorbed by the sugars. To test the supposition that there is a relation

between chlorine and amount of water absorbed we have divided the sugars into those of high chlorine content and low chlorine content; those sugars containing .004% chlorine and less are grouped as of low chlorine, and those containing more than .004% as of high chlorine content.

The average amount of water absorbed by the sugars of low chlorine content is .90%, and by those of high chlorine content 1.56%. We do not attribute of course this great difference entirely to the presence of chlorides, but regard it as evidence that a high content of chlorides in the juice and consequently in the sugars, is a cause of "sweating" of sugars. A large amount of chlorides in sugars may perhaps be connected with irrigation with saline water, with the presence of chlorides in fertilizers, or in the soil itself.

That the presence of chlorides is not the only cause of the absorption of a large amount of water is seen on reference to the results put forward in the table; for example, the sugars 19 and 37 A, remarkable for absorbing much water, are very low in chlorides, and the sugars 39 A and 39 B, both high in chlorides, are not remarkable for the amount of water absorbed.

*The effect of small quantities of salts on the hygroscopic nature of sugars.*

In the previous paragraph we brought forward evidence to show that a connection exists between the amount of chlorine present and the hygroscopic nature of a sugar. The amounts of chlorine are in most cases very small, and it seems unreasonable that so small a quantity of chloride could affect the properties of the sugar in so high a degree. This point was put to the test in the following experiment.

A solution of calcium chloride, containing .1 gram in 50 c. c. of absolute alcohol was prepared, and of this solution 5 c. c. were evenly distributed over 10 grams of a pure granulated sugar contained in a flat dish. The dish and its contents were then dried, and a sugar containing .1% of calcium chloride as impurity was thus obtained.

In a similar way, by dissolving .2 gram calcium chloride in 50 c. c. absolute alcohol a sugar with .2% calcium chloride as impurity was obtained. These sugars were then exposed in thin layers, after complete drying at 105° C., in flat dishes to



the action of the atmosphere for 24 hours, and the increase in weight due to absorption of moisture observed; a check experiment with untreated sugar gave the amount of moisture absorbed by the sugar and its container.

The details of the experiment are as below:

Calcium Chloride per cent on Sugar	Moisture Absorbed per cent on Sugar	Moisture due to Calcium Chloride
.0	.09	...
.1	.37	.28
.1	.37	.28
.2	.47	.38
.2	.49	.40

That is to say, when .1% calcium chloride is present it apparently absorbs 2.8 times its own weight of water, and when .2% is present it apparently absorbs 1.95 times its own weight.

In this experiment the difference between the dry and wet bulb thermometer was  $5.4^{\circ}$  C. Different results were obtained in other experiments when there was a greater humidity in the atmosphere. in one instance the calcium chloride absorbing apparently seven times its own weight of water. Calcium chloride itself was found to absorb 36.4% of water calculated on its weight when dry.

This effect, which has a distinct bearing on the subject of this bulletin, we are inclined to regard as due to a contact reaction between calcium chloride, water and sugar, the calcium chloride first absorbing water, the water absorbed then dissolving the sugar and rendering the calcium chloride free to absorb more water; in this sense the calcium chloride acts merely as a carrier of water to the non-hygroscopic sugar.

*Connection between glucose in sugars and moisture absorbed.*

The average amount of glucose in the sugars examined was .78%; we have separated the sugars into two portions; those containing more than .78% glucose, and those containing less than .78% glucose, and have set out the results in Table IV, together with the amount of water absorbed on standing for 24 hours. The sugars with low glucose absorbed less than those with high glucose, but the difference is not very pronounced, and does not lead to any definite statements.

TABLE IV.

Reference No.	High Glucose Glucose % on Sugar	Moisture absorbed on exposure to atmosphere for 24 hours	Reference No.	Low Glucose Glucose % on Sugar	Moisture absorbed on exposure to atmosphere for 24 hours
2AB	1.87	2.62	13 A	.36	1.27
2A	.86	1.75	13AA	.60	1.13
5A	.83	1.03	20	.48	.85
21	.82	.95	6	.68	.69
7A	.83	.49	17	.64	1.34
7AA	.80	1.48	65B	.77	1.13
12 Washed	2.91	1.77	33A	.44	1.12
43	.84	.79	33AD	.73	1.13
41 B	1.08	1.44	41A	.50	.80
27B	1.48	2.03	27A	.55	.73
9	.92	.22	24A	.43	.95
34	.83	1.08	19	.61	2.03
3A	1.06	1.41	4	.21	.22
1	1.81	1.38	12 First	.66	2.16
25	1.81	1.38	36 A	.60	.34
Average	1.20	1.32	36B	.52	.99
			37A	.18	1.59
			37B	.74	1.12
			45	.37	.37
			23A	.47	1.67
			23B	.48	2.91
			39A	.30	.71
			39B	.32	.78
			30	.61	.73
			16 Syrup	.41	.18
			16 Syrup & Molasses	.56	.47
			Average	.51	1.05

### *Examination of "Sweated" Sugars.*

During the time that the analyses and experiments detailed in this bulletin were in progress we had referred to us for examination two samples of "sweated" sugars. These sugars had sweated in the hold of the vessels by which they were shipped, and other sugars of similar origin had not sweated. The sugars that had sweated had fallen in polarization on an average five units below that which had remained sound. In the bacteriological examination of these sugars we found the organisms which

we have come to associate with deteriorated sugars, but as they came to us the number of organisms in the sweated sugars was only a few more than in the sound sugars. A decrease in the number of organisms on storage has already been noted in the case of sugars that have deteriorated, and in the absence of further evidence some similar cause may have been at work here.

In these sugars we determined the amount of water absorbed (in the way already described) and the amount of chlorine in the sugars. The following results were obtained:

Reference No.	Amount of Water Absorbed	Chlorine per cent. on Sugars
43 Sweated	3.18	.014
43 "	3.58	.018
43 Sound	.96	.012
21 Sweated	2.58	.008
21 Sound	.94	.004

In all cases the "sweated" sugars are much more hygroscopic than sound sugars of the same shipment, but with the data to hand it is impossible to say if this high absorption of water is due to bodies already present or to products of decomposition due to bacterial action. In the experiment on storage of sterile sugars we had sugars of the same origin which had deteriorated and others which, being nearly sterile, had not. This gave us a means of checking the effect of the products of bacteria on the amount of water absorbed by the same sugar. It was found that the sterilized sugar and the infected sugar which had deteriorated both absorbed the same amount of water when examined as already described. In the actual experiment the percentage of water absorbed was 1.45% in both cases. This experiment would lead to the conclusion that the "sweated" sugars had sweated on account of the presence of certain impurities, and that then, due to the favorable conditions, bacteria had been responsible for the fall in polarization.

#### *Use of "proofed" bags.*

In certain districts, particularly where direct consumption sugars are made, it is not unusual to protect the product by the use of an interior bag of specially prepared paper.

To test the benefit of the use of such bags we made the following experiments. Samples of bags sold and used for this purpose were obtained; the bags were made of a paper material, crinkled so as to be very elastic, and had been treated with some material rendering them resistant to the action of water; from this material we had made small bags holding about one pound of sugar, and similar bags from the burlap material in general use.

Into these bags was filled a raw sugar which had just been completely dried; the bags were, after filling, closed as tightly as possible, and allowed to stand exposed to the atmosphere for 24 hours; after the expiration of this time determinations of the water in the sugars in the paper and burlap bags were made with the following results:

Paper bags .....	.55%
Burlap bags .....	.57%

The bags were allowed to remain a week, when determinations of the moisture were again made.

Paper bags .....	.74%
Burlap bags .....	.80%

The bags were then placed in a very wet atmosphere obtained by placing them in a large covered vessel at the bottom of which was a layer of water. After one week the bags were removed; the sugar in the burlap bags had sweated, and to outward appearance that in the paper bags had remained sound. On opening the bags the sugar in both paper and burlap bags was found to be exceedingly moist. Actually the moisture was found to be

Paper bags .....	4.09%
Burlap bags .....	5.97%

As the result of these experiments we cannot say that the use of an interior lining of specially prepared paper will prevent the sugars absorbing moisture. To a certain extent such a scheme may be expected to mitigate "sweat damage;" whether it would be a practical scheme or not will depend on the cost of the bags and the amount of sugar their use will save from damage. This is a matter that can only be settled by a large scale experiment *in situ*, and we suggest such an experiment

as worthy of trial in any factory which is obliged to store its sugars over long periods in unfavourable localities.

From a communication from a firm making these bags we gather that the extra cost—not including extra labor—would be from 50c. to 60c. per ton of sugar.

#### *Infection from bags.*

We referred above to a statement tracing the origin of the organisms causing deterioration to the bags in which the sugar is packed. This observation we were unable to confirm. We obtained bags from four different plantations taken at random from stocks, and made inoculations from these bags into sterile nutrient agar, incubating the infected agar at 35° C. Three of the bags were apparently sterile; that is to say, from 1 gram of bag, treated as above, we obtained no colonies of micro-organisms; from a fourth bag we obtained large numbers of colonies, but the organisms occurring in these colonies were different to those which we had observed in the sugars we had previously examined.

#### *Suggestions towards preventing deterioration.*

Provided that a sterile sugar could be made, that it could be kept sterile, there is no doubt that a very great part of the loss due to deterioration could be prevented. It is a matter of no inconsiderable difficulty to sterilize even small articles in the laboratory, and the sterilization of so large a matter as a sugar factory may be regarded as impossible. In one of his communications Grieg Smith<sup>12</sup> shows that in Australia the organism *Bacillus leviformans*, which he associates with deterioration, exists in the juices and syrups at all stages of manufacture, and hence its presence in the sugars is unavoidable. Similarly, the presence of micro-organisms has been noted by Laxa<sup>13</sup> in all stages of manufacture in beet sugar factories. Notwithstanding this, we think that all efforts toward a clean factory and to a rapid process of manufacture will be well rewarded. The place in the sugar factory most suited to the development of micro-organisms is the tanks used for storage of after massecuites, and to the remelting of these sugars is to be attributed the introduction of many micro-organisms. This is not, however, the sole cause, as amongst

the sugars we examined were some which came from a factory using a crystallization in motion process, and these contained a very large number of micro-organisms.

Provided sugars are dry, no danger from bacterial damage is to be apprehended; dryness in sugars can be obtained by artificial drying by heat, but if such dried sugars are stored for any length of time they will, under unfavorable conditions, absorb moisture. To a limited extent we think that the use of an interior "proofed" bag is worthy of trial where sugars have to be stored under unfavorable conditions. With regard to treatment of sugars we have shown how that the action of small quantities of alkalis on dextrose gives rise to hygroscopic decomposition products, and consequently any excess of lime, particularly with juices containing much glucose, will tend to give a hygroscopic sugar, and hence one liable to deterioration.

A thick, viscous material, such as molasses, is not a medium well suited to the development of micro-organisms, but if the film of molasses be diluted, as will occur if the sugars are washed, a more suitable habitat for their development is formed. The sugars we have examined afford evidence that washed sugars are liable to deterioration, and we would add that the use of any but distilled water in washing sugars is a process likely to introduce large numbers of micro-organisms.

*Validity of a "count" of the micro-organisms in a sugar in connection with deterioration.*

Although the determinations we have made point to a distinct connection between bacterial activity and deterioration, an inspection of the results recorded presents points that require further study.

We have mentioned that in the case of three sugars which deteriorated the "count" of the organisms found did not afford evidence to correlate the deterioration with bacterial activity; and further, in the sweated sugars we examined, we found no great number of organisms.

Mr. C. F. Eckart called our attention to somewhat parallel observations in the region of soil bacteriology. In Bulletin 194, U. S. Department of Agriculture, Drs. Voorhees and Lipman have reviewed the work that has been done up to date in soil bacteriology. Quoting from this publication we read:

"The same fact is recognized by Chester when he says that a soil may be low in numbers of bacteria, but contain such a bacterial flora, or combination of bacterial species which are known to be favorable to the rapid digestion of plant food, as to give what might be termed a high bacterial potential."

In the same way it does not seem unreasonable to suggest that in the case of deterioration of sugars it may not be only the number of organisms at work, but also what Chester calls the "bacterial potential."

*Increase in Polarization on Storage.*

We called attention in our abstract of previous work on the storage of sugar to the statement of Watts regarding an increase in the polarization of sugars. In the course of the work described in this Bulletin we have come across similar instances. The initial polarization of the sugar 3 B was 93.7, and after storing for two months and for four months the polarization had increased to 95.0 and to 95.2. Initially the percentage of reducing sugars was 1.65, and at the end of four months it had fallen to .22%. At the same time there had been a progressive increase in the number of organisms from 28 to 420, and to a very large number at the end of four months, and the only explanation we can offer of this behaviour is that of a selective action of the organisms present towards the reducing sugars, the cane sugar remaining unaffected.

During the time that this work was in progress a similar phenomenon was noticed in some sugars analyzed in the ordinary routine work of the station. On November 27th three second grade sugars gave the following results:

No.	Polarization
2	94.05
3	93.95
4	93.8

These sugars were polarized in duplicate by different analysts, with concordant results.

On December 19th the Station was requested to repeat the analysis, on the remainder of the samples, when the following results were obtained:

No.	Polarization
2	94.9
3	95.0
4	95.1

### Summary.

1. In the great majority of cases of deterioration of sugars the fall in polarization can be connected with bacterial activity.
2. Sugars may fall in polarization without evidence of this fall being due to bacterial activity.
3. For bacterial action to take place a certain amount of moisture must be present; so long as the sugars do not contain more than 1% of moisture, the danger of bacterial action is small.
4. Four distinct organisms are of frequent occurrence in Hawaiian sugars, one of which was of very frequent occurrence in sugars which deteriorated; these are now being studied.
5. The capacity of sugars for absorbing moisture varies largely, and this is an important factor in determining the qualities of the sugars, some evidence exists that the amount of moisture absorbed is connected with the amount of chlorides in the sugars.
6. A sugar when dried will, when exposed to a damp atmosphere, absorb moisture; such a sugar will then be in a condition liable to deterioration. In factories which experience trouble with deterioration of sugars we suggest the experimental use of an interior paper lining as a means of protecting the sugar from atmospheric changes.

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**DIVISION OF AGRICULTURE AND CHEMISTRY**

**BULLETIN NO. 25**

**REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION**

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**Results from Stripping  
Experiments.**

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**BY C. F. ECKART**

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**HONOLULU, T. H.  
1908**

# HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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**REPORT OF WORK  
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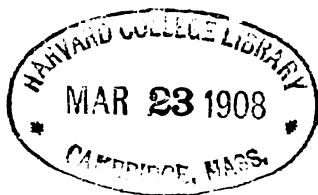
**Results from Stripping  
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**HONOLULU, T. H.  
1908**



*Book 1000*

## LETTER OF TRANSMITTAL.

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To the Experiment Station Committee of the Hawaiian Sugar  
Planters' Association.

Dear Sirs:—I, herewith, submit for publication as Bulletin  
No. 25, of the Division of Agriculture and Chemistry, the results  
from a series of Stripping Tests conducted at the Experiment  
Station.

Yours very truly,

C. F. ECKART,

Director, Division of Agriculture and Chemistry.

Honolulu, Hawaii, Feb. 12th, 1908.





## RESULTS FROM STRIPPING EXPERIMENTS.

BY C. F. ECKART.

In June, 1906, a bulletin (No. 16), entitled: "The Influence of Stripping on the Yields of Cane and Sugar," was published by this Division of the Experiment Station, and data were presented showing the relative yields obtained from stripped and unstripped cane in three series of experiments. In this bulletin the results from the ratoon crop of the second series of tests are given along with the results derived from the plant crop. This bulletin is therefore supplementary to Bulletin No. 16, and considers the yields of cane and sugar from two crops on fourteen plats in the Station field.

The plant cane (Lahaina) was planted in June, 1904, and harvested during the last of February and the first of March, 1906. It was stripped three times, as follows:

- 1st stripping, January 25th, 1905.
- 2nd " June 2nd, 1905.
- 3rd " November 1st, 1905.

The ratoons were cut back in July, 1906, and harvested in January, 1908. Stripping was performed on the following dates:

- 1st stripping, March 6th, 1907.
- 2nd " July 15th, 1907.
- 3rd " October 20th, 1907.

Each plat consisted of four rows, fifty feet in length, the two middle rows forming the bases of the comparisons; one of these test rows was stripped and the other was left unstripped.

With the exception of Plat No. 1, which was not fertilized, all of the cane received the same mixed fertilizer divided up into different proportions for the several applications, some of the plats receiving supplementary quantities of nitrate of soda, as was described in Bulletin No. 16, page 6. This explains the variation

in the yields from different plats, since the tests were planned to cover both fertilization and stripping. Owing to the fact that the stripped and unstripped rows in each plat were immediately adjoining, *the yields from these rows are comparable, and the average results from the fourteen plats afford positive conclusions with respect to stripping at the Experiment Station.* The fertilizer experiments are inconclusive, and will be repeated on plantation substations in accordance with the system of long, contiguous plats adopted by the Division for reasons given in Circular No. 6, page 42.

The following tables show the yields of cane and available sugar, together with the quality of the juices, from stripped and unstripped rows in fourteen plats for two crops of cane:

#### WEIGHT OF CANE PER ACRE—TONS.

Plat	Plant Cane		Ratoons		Average	
	Stripped	Not Stripped	Stripped	Not Stripped	Stripped	Not Stripped
1	93.31	90.52	57.49	71.22	75.40	80.87
2	64.73	88.34	49.09	59.72	56.91	74.03
3	71.09	98.01	48.78	67.69	59.93	82.85
4	91.78	108.33	58.45	65.99	75.11	87.16
5	67.00	111.25	56.27	64.86	61.63	88.05
6	82.55	112.21	64.73	72.04	73.64	92.12
7	73.57	97.88	62.90	62.33	68.23	80.10
8	72.22	99.49	53.97	74.79	63.09	87.14
9	78.10	91.30	63.33	80.89	70.71	86.09
10	76.27	101.93	57.62	74.74	66.94	88.33
11	64.29	97.36	56.32	77.49	60.30	87.42
12	84.16	111.82	70.13	82.15	77.14	96.98
13	67.08	94.09	60.02	81.67	63.55	87.88
14	84.51	108.38	74.61	89.69	79.56	99.03
Average	76.47	100.78	59.55	73.23	68.01	87.00

## ANALYSIS OF JUICES.

Plot	Brix				Sucrose				Purity			
	Plant 1904-6		Ratoons 1906-8		Plant 1904-6		Ratoons 1906-8		Plant 1904-6		Ratoons 1906-8	
	Stripped	Not Stripped	Stripped	Not Stripped	Stripped	Not Stripped	Stripped	Not Stripped	Stripped	Not Stripped	Stripped	Not Stripped
1	21.1	21.1	19.7	20.4	19.1	19.2	17.6	18.5	90.6	90.7	89.3	90.7
2	19.6	20.0	18.6	19.7	18.0	18.3	16.5	17.6	91.7	91.1	88.7	89.3
3	19.2	19.4	18.4	19.4	17.4	17.7	16.4	17.0	90.6	90.9	89.1	87.6
4	19.3	19.8	17.8	18.7	17.4	18.0	15.6	16.3	90.2	90.9	87.6	87.2
5	16.7	19.2	17.8	18.8	14.7	17.3	15.5	16.5	87.6	90.1	87.1	87.8
6	18.8	19.0	17.5	18.4	16.9	17.1	15.2	16.1	89.4	89.7	86.9	87.5
7	17.6	18.5	17.9	18.8	15.4	16.5	15.3	16.4	87.5	88.9	85.5	87.2
8	19.0	18.9	18.1	19.3	16.9	16.9	15.8	17.0	88.6	89.5	87.3	88.1
9	19.5	20.5	18.5	19.2	17.7	18.7	16.4	17.1	90.6	91.0	88.6	89.0
10	19.4	19.6	18.2	19.6	17.4	17.7	16.0	17.4	89.8	90.4	87.9	88.8
11	17.6	19.8	18.6	18.6	15.7	17.8	16.1	16.4	88.7	90.2	86.6	88.2
12	19.4	19.9	18.0	19.0	17.4	18.0	15.3	16.5	89.6	90.3	85.0	86.8
13	17.7	19.3	18.1	18.4	15.6	17.4	15.2	15.9	88.1	90.0	84.0	86.5
14	18.1	19.7	17.7	18.9	15.7	17.8	15.1	16.6	87.1	90.1	85.3	87.8
Averages	18.8	19.6	18.2	19.0	16.8	17.7	15.8	16.8	89.3	90.3	87.0	88.0

# GLUCOSE AND GUMS OF JUICE, AND FIBER PER CENT. CANE.

Plat	Glucose				Gums				Fiber of Cane			
	Plant		Ratoons		Plant		Ratoons		Plant		Ratoons	
	Stripped	Not Stripped	Stripped	Not Stripped	Stripped	Not Stripped	Stripped	Not Stripped	Stripped	Not Stripped	Stripped	Not Stripped
1	.28	.34	.47	.40	.33	.44	.17	.20	10.1	11.5	10.25	9.25
2	.30	.32	.54	.43	.34	.44	.24	.16	10.5	11.5	10.75	10.98
3	.41	.37	.56	.43	.40	.47	.23	.16	10.3	11.4	11.25	10.00
4	.43	.32	.66	.60	.38	.45	.32	.18	11.1	10.3	10.00	10.50
5	.69	.43	.66	.58	.34	.44	.10	.10	11.5	10.0	11.22	9.25
6	.56	.42	.72	.66	.44	.44	.06	.08	11.0	11.4	10.00	9.00
7	.64	.67	.71	.62	.36	.38	.14	.20	10.0	11.0	10.25	11.00
8	.57	.55	.64	.52	.40	.43	.23	.23	11.6	11.5	10.75	10.00
9	.39	.37	.59	.55	.39	.44	.19	.20	11.4	10.9	10.50	11.43
10	.50	.51	.66	.56	.35	.44	.20	.22	10.3	11.6	10.25	10.00
11	.50	.40	.63	.61	.46	.44	.20	.21	11.7	11.1	9.50	9.75
12	.48	.40	.77	.50	.38	.43	.20	.21	10.4	11.0	9.25	12.50
13	.57	.41	.77	.74	.43	.41	.21	.20	11.1	11.0	10.75	11.00
14	.57	.45	.88	.69	.42	.46	.19	.20	10.5	10.9	11.00	10.5
Averages	.49	.42	.66	.56	.38	.43	.19	.18	10.8	11.1	10.40	10.36

## WEIGHT OF AVAILABLE SUGAR—TONS.

Plat	Plant 1904-6		Ratoons 1906-8		Average	
	Stripped	Not Stripped	Stripped	Not Stripped	Stripped	Not Stripped
1	14.54	14.17	8.19	10.73	11.36	12.45
2	9.55	13.20	6.53	8.51	8.04	10.80
3	10.12	14.17	6.47	9.23	8.29	11.70
4	13.05	15.94	7.31	8.61	10.18	12.27
5	7.90	15.69	6.97	8.59	7.43	12.14
6	11.29	15.59	7.86	9.29	9.57	12.44
7	9.10	13.03	7.63	8.20	8.36	10.61
8	9.84	13.69	6.82	10.22	8.33	11.95
9	11.20	13.95	8.37	11.18	9.78	12.56
10	10.79	14.72	7.40	10.49	9.09	12.60
11	8.14	14.15	7.23	10.22	7.68	12.18
12	11.89	16.43	8.48	10.82	10.18	13.62
13	8.42	13.34	7.16	10.35	7.79	11.84
14	10.66	15.88	8.92	11.95	9.79	13.91
Average	10.46	14.56	7.52	9.88	8.99	12.21

Nothing in the way of an experiment could offer more convincing proof than these figures that stripping causes an enormous loss under such conditions as obtain at the Experiment Station. In condensed form the data may be presented as follows:

#### WEIGHT OF CANE. TONS PER ACRE.

	Stripped	Not Stripped
Plant Cane .....	<b>76.47</b>	<b>100.78</b>
Ratoons .....	<b>59.55</b>	<b>73.23</b>
Average .....	<b>68.01</b>	<b>87.00</b>

#### SUCROSE IN JUICE. PER CENT.

	Stripped	Not Stripped
Plant Cane .....	<b>16.8</b>	<b>17.7</b>
Ratoons .....	<b>15.8</b>	<b>16.8</b>

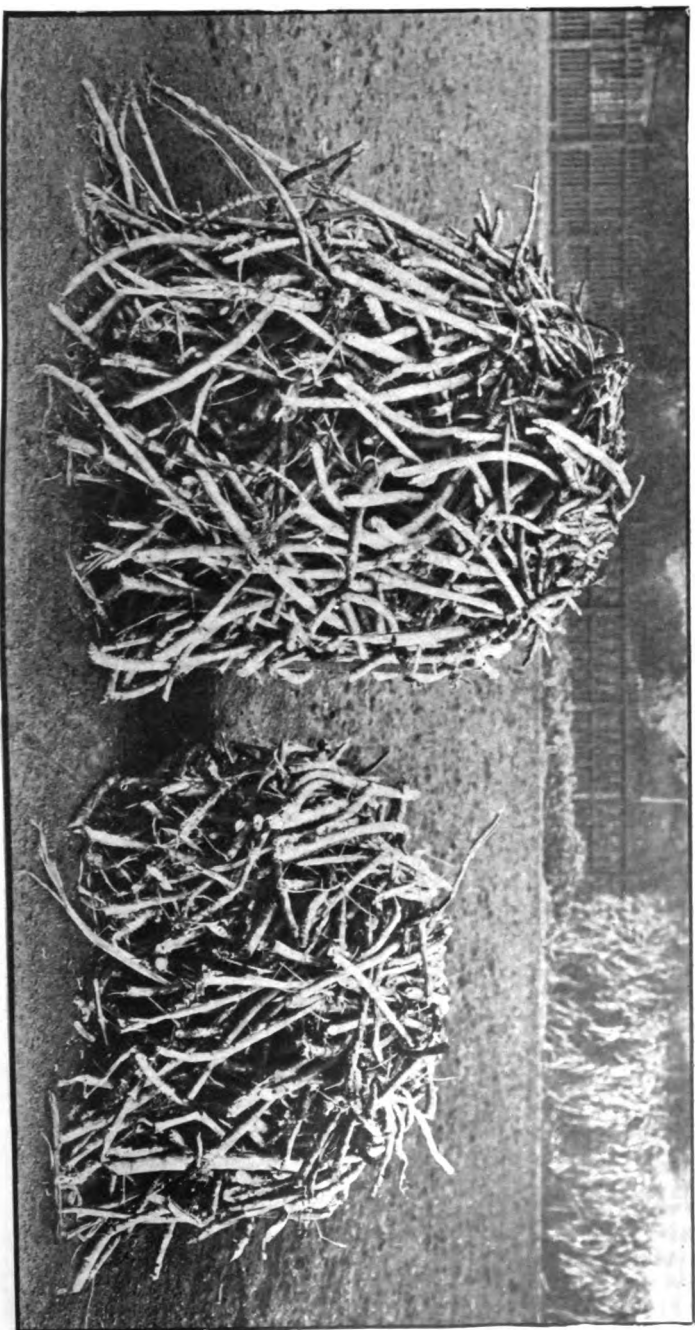
#### PURITY IN JUICE.

	Stripped	Not Stripped
Plant Cane .....	<b>89.3</b>	<b>90.3</b>
Ratoons .....	<b>87.0</b>	<b>88.0</b>

#### AVAILABLE SUGAR PER ACRE. TONS

	Stripped	Not Stripped
Plant Cane .....	<b>10.46</b>	<b>14.56</b>
Ratoons .....	<b>7.52</b>	<b>9.88</b>
Average .....	<b>8.99</b>	<b>12.21</b>

The accompanying photograph shows the relative quantities of dead cane from the stripped and unstripped rows. It would appear from the illustration that there were twice as many dead stalks where the cane was stripped than where it was left unstripped, but the difference in the size of the piles is due to some extent to the larger number of large sticks in the stack of stripped rotten cane. Where the cane was not stripped, the dead canes which were found in the rows were chiefly those that had died off when quite small; where the cane was stripped, dead sticks of all sizes were found, from young shoots to stalks which had almost reached maturity. The number of dead canes per acre are given in the following table.



A

The pile marked A shows the quantity of dead canes taken from fourteen **stripped** rows that marked B shows the dead cane taken from fourteen **unstripped** rows.

B



## NUMBER OF DEAD CANES PER ACRE.

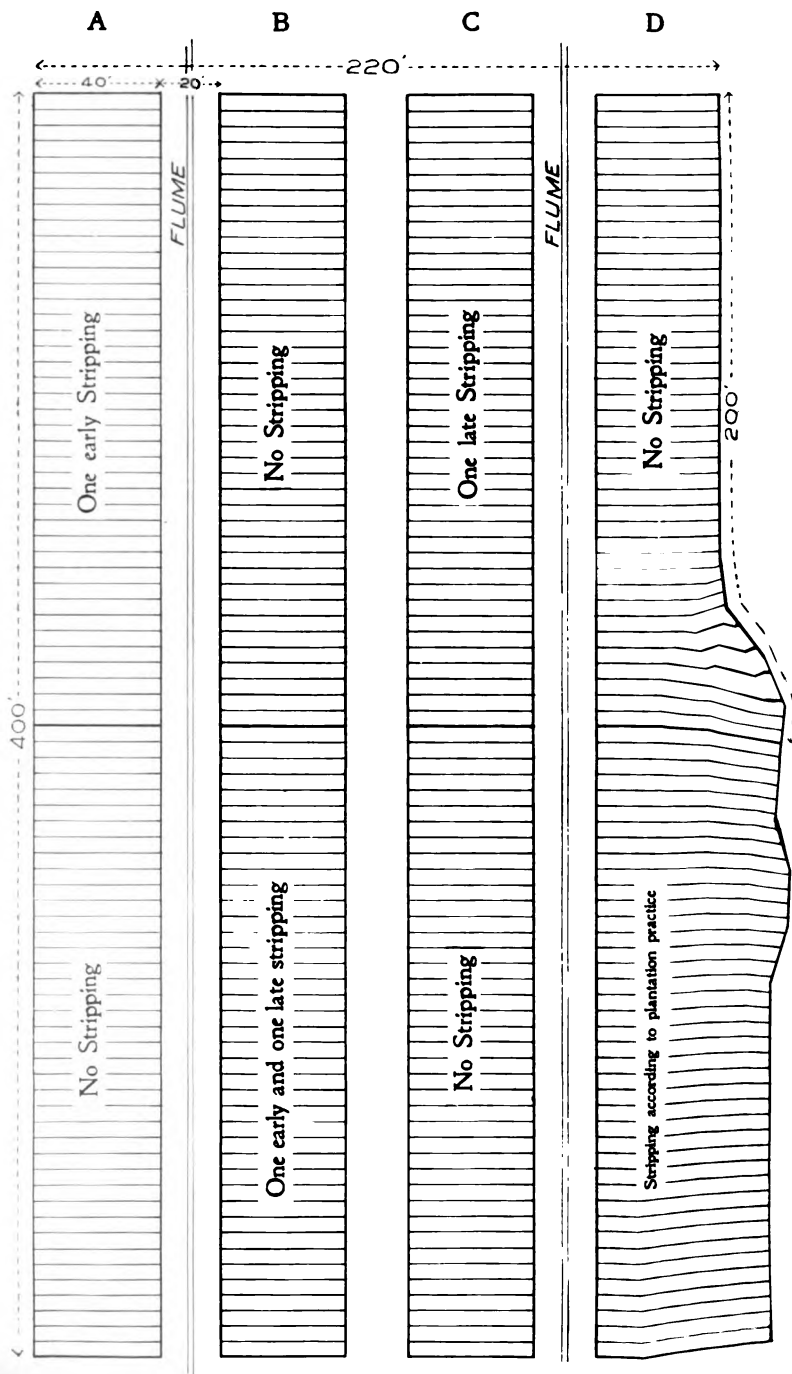
Plat	Plant Cane		Ratoons		Average	
	Stripped	Not Stripped	Stripped	Not Stripped	Stripped	Not Stripped
1	2,788	4,530	5,227	4,179	4,007	4,354
2	5,401	4,879	7,492	3,310	6,446	4,094
3	5,750	2,614	9,234	6,795	7,492	4,704
4	5,053	2,265	10,454	4,356	7,753	3,310
5	9,060	3,485	7,492	10,280	8,276	6,882
6	5,227	2,439	8,189	9,583	6,708	6,011
7	8,886	7,144	9,757	9,234	9,321	8,189
8	5,227	3,833	8,015	7,143	6,621	5,488
9	6,098	3,659	9,757	6,795	7,927	5,227
10	7,841	3,833	10,628	9,060	9,234	6,446
11	6,447	5,227	9,757	7,840	8,102	6,533
12	5,924	3,659	7,840	6,446	6,882	5,052
13	9,235	4,879	7,492	5,924	8,363	5,401
14	8,189	3,136	8,015	8,015	8,102	5,575
Average	6,509	3,970	8,525	7,068	7,516	5,519

The data contained in this bulletin, together with that presented in Bulletin No. 16, show clearly the importance of carrying out accurate tests, with respect to stripping, on the plantations. If it should be found that the practice of removing the dead leaves from the cane results, on the average, in a tithe of the percentage of loss which occurs in the Experiment Station field, the decreased yields from stripping would represent for the Islands an almost incredible figure. Last year on the Island of Oahu alone, approximately 90,158 tons of sugar were obtained from stripped cane. If we could say that the average percentage of loss from stripping for the Island of Oahu was only *one-half* that at the Experiment Station, then the loss for last crop would have been approximately \$1,210,350. This figure does not take into

consideration the cost of stripping, but is based entirely on the yields of sugar. As far as I am able to learn, 323,800 tons of sugar were obtained from stripped cane on Hawaiian plantations for the crop of 1907. If the average percentage of loss from stripping was *one-third* of that experienced at the Station, this practice cost the plantations in sugar alone, for one year, nearly *three million dollars*.

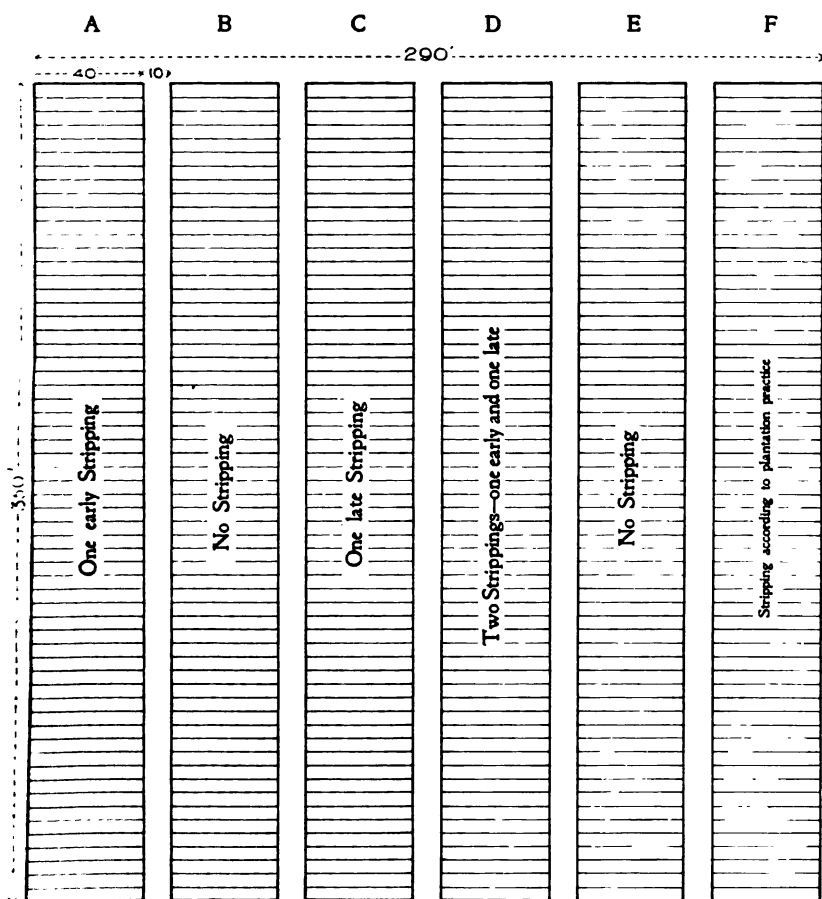
In carrying out field tests to gauge the economy of stripping in any locality, it is necessary that every possible safeguard to accuracy be observed, and the Division would strongly recommend the laying out of experiment areas in accordance with the following plans. These plans call for long, narrow plats. The greater the length of the plats, the more accurate will be the results.

# EXPERIMENT FIELD FOR STRIPPING TESTS ON IRRIGATED PLANTATIONS.



Where the plantation practice conforms with the treatment called for by any one of Plats 1, 3 or 6, Plat 8 should be made a three stripping test

# **EXPERIMENT FIELD FOR STRIPPING TESTS ON UNIRRIGATED PLANTATIONS.**



Where the plantation practise conforms with the treatment called for by any one of Plats A, C or D, Plat F should be made a *three* strippings test.





# HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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**REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION**

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**Varieties of Cane  
With Special Reference to Nomenclature**

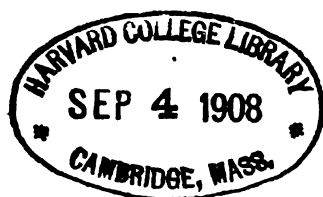
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**BY NOËL DEERR AND C. F. ECKART**

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**HONOLULU, HAWAII  
1908**





*The Station*

## LETTER OF TRANSMITTAL.

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To the Experiment Station Committee of the  
Hawaiian Sugar Planters' Association,  
Honolulu, T. H.

Dear Sirs:—I herewith submit for publication as Bulletin No. 26 of the Division of Agriculture and Chemistry, an article entitled "Cane Varieties, With Special Reference to Nomenclature." Mr. Deerr is essentially the author of this memoir on the nomenclature of cane, since by far the greater part of it was prepared by him from notes collected during his residence in various sugar-growing countries. In view of the present confusion over variety names, I believe this bulletin will serve a useful purpose in bringing to light a number of well established synonyms.

Yours very truly,

C. F. ECKART,  
Director, Division of Agriculture & Chemistry.

Honolulu, June 26, 1908.



## ON VARIETIES OF CANE, WITH SPECIAL REFERENCE TO NOMENCLATURE.

By Noël Deerr and C. F. Eckart.

Some years ago one of us<sup>1</sup> issued, from this Division of the Hawaiian Sugar Planters' Association Experiment Station, a Bulletin on the present subject; in the present Bulletin it is our object to place on record our further experience in this matter, which we are inclined to think is of no inconsiderable importance.

Of late years the interest in varieties grown from the seed has been so great that there has been danger of neglect of the older varieties, the nomenclature of which is in a state of great confusion. Now that the practicability of growing pedigree seedling canes is firmly established, and is being successfully carried on in more than one experiment station, it is a matter of great importance that workers in one part of the world should know what canes their colleagues in another have in mind when one of these is referred to.

To this end we have made a careful study of all the literature we have available, and have combined the results of such studies with our own personal experience.

We shall be ready to receive corrections and further information from any part of the world, and if a sufficiency of such information should be vouchsafed us we shall be willing to collate and publish what we shall have received.

### THE YELLOW OTAHEITE CANE AND ITS ALLIES.

Under this heading we propose to collate the literature of the Sugar Cane dealing with cane or canes known under the terms "*Lahaina*," "*Bourbon*," "*Louzier*," "*Oatheite*," etc.

The earliest reference to this cane that we have found occurs in Wray's "Practical Sugar Planter," of date 1848. He states:

1. That the account of the origin of the "*Bourbon*" cane is not very satisfactory, the generally received opinion being that it reached the Island of Bourbon from the Malabar coast, origi-

nally being a small-sized, soft, juicy cane, which became much improved by cultivation.

2. That the "*Tibboo Leeut*" of Singapore is identical with the "*Bourbon*."

3. That the "*Otaheite*" canes are two,—the yellow, or straw colored, and the purple striped, or ribbon.\*

4. That the Otaheite was taken direct from that island to the West Indies, Calcutta, and the Straits, and that the Tibboo Leeut was introduced to the Straits from Otaheite by way of Manila.

Definitely recorded instances of the introduction of this cane we have found as follows:

1. To the island of Bourbon at an early date, thence to Martinique about the middle of the 18th century, and from this island to Cayenne and other of the French possessions in the West Indies.

2. By Sir John Palfrey directly from Otaheite to Antigua in the 18th century.

3. By Captain Bligh, directly from Otaheite to Jamaica in 1796.

4. It is generally stated that the "*Lahaina*" cane was introduced to the Hawaiian Islands by Captain Pardon Edwards, of the ship *George Washington*, and that it was brought from the Marquesas Islands; this we will show later is a mis-quotation, and that the *Lahaina* cane came also from Otaheite.

*Recently recorded notices of this cane.*

Fawcett,<sup>2</sup> in a detailed descriptive list of canes growing in the Jamaica Botanical Gardens, mentions, amongst many others, the "*Lahaina*," "*Queensland*," "*Keni Keni*," "*China*;" he does not in any way identify them, but remarks that they possess the best characteristics of the white canes.

Delteil,<sup>3</sup> in describing canes cultivated in Bourbon and Mauritius, gives as synonyms "*Batavian*" (in Bourbon), "*Yellow*" (in Mauritius), "*Bourbon*" or "*Otaheite*" (in the West Indies), "*Singapore*," "*Leeut*" (in Singapore).

Stubbs,<sup>4</sup> who has made a detailed study of the varieties collected at Audubon Park, splits the White, Green and Yellow canes into a number of groups. In Group II of his classification appears

\* For the moment this purple striped cane is not being discussed

No. 10. Yellow, from Cuba.

No. 11. Blanca de Otaheite, from Cuba.

No. 12. Loucier, or Lousier, from Mauritius, via Cuba.

Of this group Dr. Stubbs writes:

"It is difficult to find any difference between them  
on our soil . . . ."

"The leaves are covered with little prickles . . . ."

"They all came originally from the island of Tahiti  
(=Otaheite) or Madagascar."

In Group III of the same class appear

No. 13. Portier, from Cuba.

No. 14. Lahaina, from Hawaii.

No. 15. Keni-Keni, from Jamaica.

These are stated to be the same cane, and to have originated from the Marquesas Islands. It is to be noticed that Dr. Stubbs does not mention the presence of prickles on these canes.

In Group IV are the China and Green Elephant, both from Jamaica, which are stated to be closely allied to the canes in Group III, but to differ essentially in habits of growth and ratooning.

In Group VIII are the Cuban and Sacuri, also from Jamaica.

Harrison and Jenman,<sup>5</sup> in describing the canes growing in the British Guiana Botanical Gardens, give as synonymous: Bourbon, China II, Cuban, Lahaina, Bamboo II, Otaheite. They describe, but do *not* identify, in any way, canes under the names of Keni-Keni, Jamaica Elephant, Singapore, China.

Comparing the statements we have collated above, all of which come from trained and experienced observers, contradictions in nomenclature are numerous. Thus, following Stubbs, "Cuban," "Otaheite" and "Lahaina" are three different canes, whilst according to Harrison and Jenman they are identical; again, Stubbs identifies Lahaina and Keni-Keni, while Harrison and Jenman separate these canes into two varieties; further, Delteil and Wray agree in the identity of Singapore, Bourbon and Otaheite, but Harrison and Jenman divide the first named from the last two.

This confusion can, we think, be readily accounted for on the supposition that there are *two*, or more, similar but distinct canes originating in the island of Otaheite; these canes have been introduced into all cane-growing districts, and have been exchanged from district to district; in this way the names given

to these canes have multiplied, and the name proper to one variety has become attached to another; and in all probability where these canes are cultivated the two or more varieties may be growing in the same field as one variety.

We were led to this conclusion from a study of the literature of the cane, and this view is confirmed in the account of the Origin of the Lahaina Cane which we give below.

#### *Origin of the Lahaina Cane.*

Lahaina is a district in the island of Maui, in the Hawaiian Islands, whence this cane was distributed over the group, and eventually to many other cane-growing districts.

Its origin is succinctly told by Mr. D. D. Baldwin in a letter appearing in the *Hawaiian Planters' Monthly*, for May, 1882, and the information there throws much light on the question discussed above, and goes far to prove that there are at least *two* varieties of Otaheite canes.

Mr. Baldwin states that in 1854 Capt. Edwards, in the ship George Washington, brought *two* varieties of cane from Otaheite (*not* from the Marquesas); these two varieties are now (1882) known as Cuban and Lahaina, the "Cuban" also obtaining the name "Oudinot." To the "Cuban" was also applied the term Kenikeni, from the native term Kinikini—numerous, in reference to the prolific nature of the cane.

Mr. Baldwin thus distinguishes between these two canes.

*Lahaina.* Long straight leaves of light color, heavily aculeated, or covered with prickles at the base, with small round prominent buds.

*Cuban.* Leaves of darker green, bending down in graceful curves, with no prickles, and large triangular buds located in little cavities on the side of the cane stalk.

Mr. Baldwin further states that in 1861-2, Cuban was the favorite cane, and that it afterwards gave way to Lahaina, the latter possessing these advantages: rapid growth, deep rooting, hard rind when mature, superior richness of juice, firm, compact fibre, making the trash easy to handle, and enhancing its value as fuel.

That it is possible that there are two varieties of this cane is, we submit, a matter of no inconsiderable interest. The yields obtained from the Lahaina cane in the Hawaiian Islands are unsurpassed elsewhere, and under the name of Bourbon and Lousier this cane, or canes, still remains under extended culti-

vation in Demerara and Mauritius, and in the former district it has formed the basis of comparison in the extended trials, the results of which have been annually published by J. B. Harrison.

This view that the cane called Bourbon does not represent an unmixed strain is not now put forward for the first time; on entirely different lines of reasoning, and chiefly based on field observations, J. H. Hart,<sup>6</sup> in Trinidad, has expressed the view that the Bourbon cane in Trinidad includes many varieties of yellow cane.

### *Irregularities in Nomenclature.*

Delteil<sup>3</sup> states that the term Otaheite is in Bourbon applied to a purple cane, and Fawcett<sup>2</sup> also classifies a purple cane under this name. Soltwedel<sup>7</sup> illustrates the Loethers (Lousier) cane of Java as a brown cane, and in this he is followed by Kruger.<sup>8</sup> Alfred Watts<sup>9</sup> described the Lousier as grown in Pernambuco as a "dark red cane, with a very dark green, almost black, stripe, scarcely visible, turning brick red when ripe, with hard rind and very heavy." This description applies to the cane discussed below under the name "Cavengerie." Stubbs separates the Bourbon as sent to him from Trinidad from the Otaheite, etc., and identifies it with "Light Java," etc. (see below), but in a letter one of us received from him in 1903 he writes "I have long since been convinced that the Bourbon cane I have is not the Bourbon alluded to by several of the correspondents." Cousins<sup>10</sup> separates the Bourbon and Otaheite canes, and writes "..... the White Transparent or Mont Blanc cane (which would appear to be identical with the so-called Otaheite cane introduced by Captain Bligh...)..." Tie-mann,<sup>11</sup> referring to canes in Egypt, writes "This red cane springs apparently from the Bourbon, or else is identical with it."

Portii<sup>12</sup> is described in a report of date 1869, from the Royal Botanic Gardens of Mauritius, as a chalky gray colored cane, spreading in habit,—highly spoken of in the Straits. It is spoken of as likely to be one of the best sugar-producing canes in the colony (Mauritius). Portii is stated by Stubbs to have come to Cuba from Mauritius, and thence to Louisiana; this is evidently a case of name transference from one cane to another, as Stubbs positively identifies Portii as the same as Lahaina.



*Suggested Nomenclature.*

In all cases we think that the original home of a variety should be used in naming a cane, and for this reason we prefer Otaheite to Lahaina, Bourbon, Louzior, etc., although these names are firmly established, and will probably remain so in the respective districts where they are in use.

THE "BATAVIAN" OR "TRANSPARENT" CANES.

Under this heading we propose to collate the literature of the canes known as White and Purple Transparent in the British West Indies, as Rose and Dark Bamboo in these Islands, and also known under a great variety of names.

The earliest mention of these canes occurs, so far as we know, in Wray,<sup>13</sup> who writes: "The Batavian canes with which I am acquainted are of four descriptions, viz: the yellow violet, the purple violet or Java cane, the 'transparent' or ribbon cane, and the Tibboo Batavee or Batavian, of the Straits."

"The yellow violet,' so designated in the West Indies, differs from the Bourbon in being smaller, less juicy, correspondingly harder, of slower growth, and of a foliage much darker and more erect. The yellow violet does not require so rich a soil as the Otaheite, but contents itself with that of an inferior description."

Of the "purple violet" or large black cane of Java, he writes that the very upper joints sometimes exhibit faint streaks which become imperceptible in the lower joints, and that frequently the cane is encrusted with a white resinous film; in the Straits the Malays call it Tibboo Etam, or Black cane.

Of the transparent or ribbon cane he writes that it is much smaller in size than the Otaheite ribbon; that it is of a bright transparent yellow, with a number of blood red streaks or stripes.

Delteil<sup>3</sup> gives as synonymous Otaheite (in Bourbon), Belouguet (in Mauritius), Purple Batavian, Purple Violet, Tibboo Etam, and Tabor Numa. Stubbs<sup>4</sup> first group of white, green or yellow canes includes as synonyms La Pice, Panachee, Le Sasseur, Tibboo Mird (from Manila), Bourbon (from Trinidad), Crystallina, Green, Light Java, Hope.

In Group V of the same class is placed Rose Bamboo, received from Hawaii. This separation of Rose Bamboo from Tibboo Mird is remarkable, as at this Station these canes are identical,

the Tibboo Mird we have having been received directly from Louisiana.

In Group II of the striped canes, Stubbs gives four identical canes,—the Red Ribbon, Striped Mexican, Batavian, and Home Ribbon; Dr. Stubbs states that this variety came originally from Tahiti, and that it is usually known as the Otaheite Ribbon cane.

In Group III of Stubbs' third class is the Black Java, stated to be a sport from the Red Ribbon, and to be identical with the Louisiana Purple cane.

In Harrison's and Jenman's list of canes under cultivation in the British Guiana Botanical Gardens the following synonyms are given:

Red Ribbon—Seete—Striped Singapore.

White Transparent—Caledonian Queen—Mamuri—Rappoe.

Purple Transparent—Java—Purple Mauritius—Queensland Creole—Meera.

From our own experience in Demerara, Mauritius and Hawaii, we have no hesitation in saying that it is impossible to differentiate between the White Transparent or Caledonian Queen of the West Indies, and the Rose Bamboo of Hawaii and Mauritius; in addition, a cane grown to a limited extent in Mauritius under the name Striped Bamboo is identified by one of us as identical with the Red Ribbon, Striped Louisiana, etc. In Fiji the Striped Bamboo is known as Mauritius Ribbon.

In a subsequent paragraph we deal more fully with the question of sports, and for the moment we take it as established by means of the authorities that we have quoted above that the self-colored light and dark canes mentioned in the preceding lines are sports from the ribbon cane identical with that described by Wray as the "Transparent Cane," and that Wray's "Yellow Violet" is the White Transparent or Rose Bamboo, and that his "Purple Violet" is the Black Java or Louisiana Purple, or Purple Transparent. We have not been able to obtain any account of the origin of the terms Bamboo or Transparent, as applied to these self-colored canes here treated of; we are, however, inclined to connect them with the term "Striped Bamboo," as applied to the ribbon cane in Mauritius, and with Wray's term of "Transparent" or ribbon cane, and suggest that it was with full knowledge of the origin of these canes as sports from a striped cane that the names arose.

### *The Cheribon Cane.*

In the literature of the cane, especially as it relates to Java, the Cheribon cane is frequently mentioned, and it has there occupied a position analogous to that occupied in the British West Indies by the Bourbon.

One of us,<sup>14</sup> trusting to the verbal statement of a gentleman who had been for many years in Java, stated that this cane was the same as one discussed below as the Striped Tanna; this statement we now know to be quite incorrect. The description of this cane by Kruger leaves no doubt that this cane is none other than that already described as "Black Java," "Purple Transparent," and "Queensland Creole." A categorical statement to this effect, which we quote below, has lately appeared, due to Kruger:<sup>15</sup> "In Barbados a little Bourbon still is grown, but the 'Purple Transparent' (probably identical with the Cheribon) is chiefly planted, then the 'Ribbon Transparent' and the 'White Transparent' (which are presumably the Striped Cheribon and the White Cheribon)."

### *Synonymy.*

To these canes have been given a great number of names, which we collect below:

*Striped variety.* Transparent, Striped Mexican, Louisiana Striped, San Salvador, Striped Singapore, Striped Bamboo, Red Ribbon, Seete, Striped Cheribon, Home Ribbon, Mauritius Ribbon. A cane very similar to this striped variety has been grown in Fiji, we understand, under the name of Striped or Mauritius Gingham. Its distinguishing features are the absence of bloom and its great susceptibility to gumming disease.

*Light colored variety.* Yellow Violet, La Pice, Le Sassier, Panachee, Rose Bamboo, Mexican Bamboo, White Transparent, Naga B, Blue, Hope, Light Java, Mont Blanc, Rappoh, Crystallina, Tibboo Mird, Green, Mamuri, Yellow Singapore.\*

*Dark colored variety.* Louisiana Purple, Black Java, Purple Transparent, Black Cheribon, Tibboo Etam, Purple Violet, Belouguet, Tabor Numa, Queensland Creole, Purple Mauritius, Purple Bamboo, Moore's Purple.

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\* In Fiji the Yellow Singapore and Rose Bamboo are, we understand, distinguished from each other by a difference in the degree of tasselling, a characteristic which might possibly be influenced by previous environment.

*Irregularities in Nomenclature.*

Delteil<sup>3</sup> gives Otaheite as a synonym of the dark colored variety in Bourbon, whence perhaps comes the purple cane called Otaheite by Fawcett. Cousins<sup>10</sup> suggests that the White Transparent or Mont Blanc cane is identical with the so-called Otaheite cane introduced by Capt. Bligh into Jamaica. Stubbs' inclusion of Bourbon amongst the other synonyms of the light colored variety, and his separation of Rose Bamboo have already been discussed; he further states that the striped variety came originally from Tahiti, and is generally known as the Otaheite Ribbon cane; Wray, however, particularly distinguishes between the "Transparent" cane and the Otaheite Ribbon cane, which, from Wray's description we take to be that discussed below under the name Striped Tanna. Harrison and Jenman<sup>5</sup> give Meera as a synonym of their Purple Transparent; Meera is a Malay term for red, and the Tibboo Meera of Java described and figured by Soltwedel<sup>7</sup> is a dull brick red cane quite distinct from the Purple Transparent. Soltwedel figures Tibboo Rappoh as a cane of a peculiar greenish brown color, with a well marked bluish white layer of wax (?) at the node, and Tibboo Rappoh Kiang as a purplish cane.

Judging from a report<sup>12</sup> on new varieties of canes from the Royal Botanical Gardens of Mauritius, for 1869, Rappoh seems to be a generic term applied to canes, similar to the East Indian terms Meera—any red cane, or Soerat—any striped cane; probably one of these varieties identical with the Rose Bamboo, etc., has found its way to Queensland, where the term Rappoh has become restricted to it and it alone. In the report mentioned, the term Rappoh appears as under: "Rappoe (a worthless variety) . . . . . Rappoe Maeda . . . . . Rappoe Koenig (apparently a worthless variety) . . . . . Aboe White or White Rappoe."

In a very early reference in the Annual of Scientific Discovery, 1851, mention is made of Crystallina, Chalk or Salangore, recently introduced into Louisiana, and superior to any other variety. Tryon<sup>16</sup> mentions that the cane called Cheribon in Queensland is the same as that called Port Mackay (see *Cavengerie* below). Fawcett describes Seete as a green cane, white when ripe, and Dahl and Arendrup<sup>17</sup> also give it as a greenish yellow, or white, cane.

*Suggested Nomenclature.*

The terms "Bamboo" and "Transparent" are firmly attached to these varieties, but nevertheless we think that a topographical nomenclature would be more proper. Wray, the earliest authority, does not trace this cane to Otaheite, and distinctly calls them Batavian canes, hence the terms Light, Purple and Striped Java would be suitable; in Java they are known as the White, Black and Striped Cheribon canes, and as such they are frequently mentioned in the Java "Archief." For this reason we think that "Cheribon" is the best term to apply to them, as in this way a topographical system of nomenclature is retained.

THE YELLOW CALEDONIA AND TANNA CANES.

In Bulletin No. 10 of the Division of Agriculture and Chemistry one of us wrote.

"White Bamboo, Queensland No. 7, Yellow Caledonia, and the unstriped cane which occasionally appears in a stool of Big Ribbon are closely allied; in fact, between White Bamboo and Yellow Caledonia there appears to be no difference, and after four years trial it is impossible to distinguish one from the other."

This expression of opinion with respect to the apparent identity of the light colored sport from Big Ribbon with the Yellow Caledonia or White Tanna has now been entirely confirmed. We are satisfied, however, that a consignment of cuttings received at this Station under the name White Bamboo bore the name by mistake, and should have been labeled Yellow Caledonia. The fact that Queensland No 7 is a seedling cane naturally separates it from the Yellow Caledonia, although under Hawaiian conditions they bear no distinguishing external features, so far as we have observed. The following may be put down as synonyms:

Big Ribbon—Striped Tanna, also possibly Gingham and Maillard.

Yellow Caledonia—White Tanna—Malabar (in Fiji)—Green Tanna.

As regards the origin of these canes, we recall that Wray states there are two Otaheite canes, the yellow or straw-colored, and the purple stripped or ribbon; this latter he describes as much larger than the ribbon cane of Batavia, and with a much

darker foliage; its coloring he gives as a broad purple stripe on a greenish yellow ground, as contrasted with the blood red stripes on a transparent straw-colored ground of the Batavian ribbon cane; this description, so far as it goes, fits the Big Ribbon, and Delteil gives the following synonymy:

Otaheite Ribbon (Wray)—Gingham—Maillard—Tabor Soerat\* (in Java).

In a verbal communication, however, to one of us, Mr. James Clark has referred to the Striped or Mauritius Gingham as being subject to "gumming" more than other varieties grown in Fiji; this would lead one to doubt the definite identification of Otaheite Ribbon with Big Ribbon. The latter as a Tanna cane is known to be especially resistant to gumming in Queensland. Mr. Clark, who is well acquainted with the Striped Tanna variety, has, to one of us, likened the Mauritius Gingham to the Striped Singapore, and mentioned the absence of bloom as its chief differing characteristic. It is therefore possible that either Otaheite Ribbon is not synonymous with Big Ribbon, or that there are two distinct canes grown under the name of Gingham. As we have found references to a cane called "False Gingham," it is possible that this is the variety grown in Fiji.

Wray also describes, but not too clearly, a cane originating from the island of Tanna, in the New Hebrides. He says "The Tibboo Teelor (or egg cane) has long been deemed to be the Otaheite cane by the planters of Province Wellesley, but quite erroneously. It is evidently the cane described by Cook and other navigators as peculiar to the island of Tanna, one of the New Hebrides." The quotation from Cook's *Voyages*, quoted from memory by Wray, is given correctly below:<sup>18</sup>

"The bread-fruit, cocoanuts and plantains are neither so plentiful nor so good as at Otaheite; on the other hand, sugar canes and yams are not only in greater plenty, but of superior quality and much larger."

Wray states that this cane was introduced into Manila many years ago, (he wrote in 1848), and thence found its way to Singapore; he remarks on its extreme cleanness and absence of itch, the curious manner in which it bulges out between the joints, its peculiarity in shedding its leaves as they become dry, and on its brittle nature. With the exception of the bulging internodes

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\* This last term is confusing, as the name simply means Ribbon cane, and is applied to any ribbon cane.

this description tallies closely with that of the Yellow Caledonia or White Tanna, and it is possible that this is the same cane that Wray describes as Tibboo Teelor, and attributes to the Island of Tanna. This island lies quite close to New Caledonia, and it is reasonable to suppose that the same varieties of cane would exist in the two islands; the name "Yellow Caledonia" then may connect the origin of this cane with the island of New Caledonia. If Wray's New Hebrides cane was called "Tibboo Teelor" or egg cane from the fact that the internodes were sufficiently oval to suggest such a name naturally it was distinct from our Yellow Caledonia of to-day. Concerning the origin of the term "Tibboo Teelor" we have found no information.

Of the cane known as Black Tanna we have found no synonyms.

*Irregularity in Nomenclature.*

Kruger<sup>8</sup> describes as Tibboo Kunning or Tibboo Teelor a cane of a handsome yolk yellow coloring, with very conspicuous depressions at the eyes, and with more or less convex internodes; this cane is figured by Soltwedel, but the colored drawing does not correspond with the cane that we know as Yellow Caledonia.

THE SALANGORE CANE.

This variety is not cultivated in these Islands, and when tried experimentally some years ago at the Experiment Station was so pronounced a failure that its further trial was abandoned. It is cultivated apparently to some extent in Porto Rico, since Cook and Collins<sup>19</sup> write ". . . but the Salangore variety has been preferred of late years, as more resistant to disease."

The history of this variety, so far as we have been able to trace it, is as follows:

Wray,<sup>13</sup> writing in 1848, speaks in the highest terms of the variety, calling it the finest in the world; he gives as synonyms the native terms Tibboo Capor and Tibboo Beltong Berabou, and comments on the large amount of cane wax found on the stem.

A second early reference occurs in the Annual of Scientific Discovery, 1851, when it is stated that the Crystallina, or Chalk, or Salangore cane recently introduced into Louisiana is superior to any other.

Delteil<sup>3</sup> gives as synonyms of the Salangore, Chinese cane (in Bourbon) and Penang cane; he describes it as a green cane covered with a dirty greyish brown wax, and says that in Bourbon

and Mauritius planters are far from sharing Wray's opinion. Harrison and Jenman<sup>5</sup> give as a synonym (in Demerara), White Mauritius, and describe it as much under average height, much under average length of internodes, and of nearly average girth, while Fawcett describes it as of stout, upright habit, and of rapid and luxuriant growth.

Another reference appears in an anonymous contribution dealing with Queensland canes:<sup>20</sup> "A cane which I think would do well there is the Salangore. It is of very erect habit, ratoons well, and yields a juice rich in saccharine matter, and easy of clarification. It has somewhat more fiber than the Otaheite, and grows the greatest weight per foot of any cane I have ever seen, sometimes almost two pounds weight per foot of cane."

These descriptions are so diametrically opposed that it might appear that two canes are included in the name Salangore, but this peculiarity of giving both heavy and scanty crops is thus referred to by Harrison:<sup>21</sup>

"Some of us will doubtless recollect the time when Mr. A. would plant a few acres of Salangore cane in the hopes of getting better field returns and richer cane juice; how these Salangores in some years flourished and raised hopes of heavy returns of sugar; how in others they unaccountably languished; but how, whether they flourished or languished, one thing invariably characterized them—miserably poor juice and consequent loss of money."

### *Irregularities of Nomenclature.*

In the quotation from the Annual of Scientific Discovery given above, Salangore is put equal to Crystallina, and elsewhere we have quoted Crystallina as one of the synonyms of Rose Bamboo, White Transparent, etc. Purdie<sup>22</sup> in Trinidad, provisionally named two canes there Green Salangore and Violet Salangore; of the former he says that it is not so bright as a well ripened Otaheite, is of erect habit, and is the largest yellow cane in Trinidad; its foliage is large, heavy and deciduous, and it is further characterized by a broad white rim below each joint. This description coincides closely with the characteristics of a Yellow Caledonia or White Tanna cane.



### THE CAVENGERIE CANE.

This cane is given by Stubbs<sup>4</sup> as synonymous with Altamattie and Po-a-ole. The cane which we have here under the name Cavenagerie, and evidently the same as that described by Stubbs, is a dark claret cane, with a narrow, inconspicuous, yet well defined bronze green, almost black, stripe. This cane is, from the personal knowledge of one of us, to be identified with that known in Mauritius as Port Mackay, where it is under cultivation to a fair extent. In some parts of the Hawaiian Islands this cane is termed "Bullock Heart."

#### *Irregularities in Nomenclature.*

Kruger<sup>8</sup> describes a cane known in Java as Port Mackay as a yellow green cane with very handsome prominent brown blotches where sun exposed. Alfred Watts<sup>16</sup> description of the cane called Louzier in Pernambuco exactly fits the cane that we know as Cavenagerie. Tryon,<sup>16</sup> in an article on cane varieties, states that the Port Mackay of Mauritius is in Queensland called Cheribon. A cane shown to one of us when resident in Mauritius as Cavenagerie, or Seavenger, and of only occasional occurrence, was a totally distinct variety from the one we know here as Cavenagerie.

In these islands the name Altamattie has been incorrectly applied to a green cane conspicuous for an epidermal covering of hairs.

### BAMBOO CANES.

The name "Bamboo" has been applied to a large number of canes in no way connected. In a previous paragraph we have collated the references in the literature to the Rose, Purple and Striped Bamboo; references to other "Bamboo" canes are included below.

In Harrison's and Jenman's<sup>5</sup> list of canes growing in the British Guiana Botanical Gardens, Bamboo III appears as a synonym of Bourbon, and Bamboo I and II as synonymous with Meligeli and Demerara. The Bamboo described by Delteil<sup>3</sup> and by Stubbs<sup>4</sup> is by both authorities given as a synonym with the Kullore or Kulloo cane of Bengal; this cane, under the spelling Culleroah, is also referred to by Porter,<sup>23</sup> who describes it as a light colored cane, growing to a great height, and to be found on swampy ground. It is described as of a mixed yellow pale green and pink color by Delteil, Stubbs, in addition, calling attention to its enlarged nodes and prominent eyes.

A cane successful in higher elevations in these islands is that known as "Yellow Bamboo;" an account of the origin of this cane is to be found in the Hawaiian Planters' Monthly, Vol. VIII, p. 7, but we do not accept the conclusion there arrived at that this cane is a "graft." This variety can be described as a rather small yellow cane, with a narrow rich green leaf, the sheath of which is thickly covered with prickles. The internodes are slightly convex, and the eye small and round. The ground tissue is distinctly yellow.

#### RED CANES.

Wray mentions and suggests the identity of certain red canes growing in Bengal, Assam and Malacca, and states that the Malay name for these is Tibboo Merah; Kruger<sup>8</sup> mentions two canes to which this term is applied, one qualified by a place name, Tibboo Merah Borneo, and one simply as Tibboo Merah; Merah is also given as a synonym of the Purple Transparent of Demerara, and in this instance we take it that Merah is the Malay term loosely applied to any red or purple cane. Tibboo Merah is figured by Soltwedel<sup>11</sup> as a brick red cane, and from a recent visitor to this Station we understand that this is the cane also known as Merah in Queensland and Fiji.

#### THE STRIPED TIP CANE.

This cane is being grown with some success at the higher elevations in these islands. It can be described as a small, thickly stooling, erect cane, with dark red and pinkish green stripes, the dark red changing on exposure to a yellowish red, and the pinkish green to a yellow; the stripes are very irregular as to width and length. The sheaths of the young green leaves have light purplish margins, and are covered with long prickles, the latter rubbing off easily, and entirely disappearing as the leaf dries on the stem. The eye is large, long and pointed; nodes prominent; internodes concave, and slightly bulging out on the opposite side of the stem from the eye, which is situated at the base of a small groove extending from one half inch to the full length of the internode. This cane is in some parts of Hawaii occasionally confused with Striped Singapore, although the two varieties bear no resemblance to each other.

A cane which has been grown in small patches on Hawaii for some years past under the name "Unknown" has been positively

identified as a yellow sport from the Striped Tip, and in order to connect it with its parent has recently been named Yellow Tip\* by this Station. This sport may be described as a slender, thickly stooling, fairly erect, light green cane, which toward maturity turns to a yellow. The leaf is light green, and the sheaths bear very few hairs, which rub off easily, and are entirely absent in the dried leaf. The eye is large, long and projecting, and is situated in a very slight groove; the internodes are concave, and give the stalk the general appearance of bamboo. Both the Striped and Yellow Tip canes are prolific ratooners.

#### THE ELEPHANT CANE.

We make no apology for reproducing the following account of the *true* Elephant Cane, due to Sir J. D. Hooker:

"This variety is only cultivated for eating or chewing. I do not think it would prove a good sugar producing cane . . . . But varieties, especially in the case of sugar canes, often improve by change of climate. Perhaps this might have the good fortune to succeed better elsewhere. The dimensions as to diameter and height which this variety attains, depends on the length of time during which its growth continues. It requires in a good soil two years to reach 10 feet in height. After five or six years it may reach 16 to 32 feet; such specimens may be seen near native houses, where it is allowed to grow undisturbed as an ornamental plant. In the province of Mytho this variety is cultivated in humid alluvial soils on a considerable scale, but simply for sale in the bazaars and for chewing. It has the peculiarity of possessing a very brittle epidermal layer, so that instead of becoming pressed out and giving up its juice when passed through the wooden mills employed here, it breaks up into small fragments."

#### GREEN ROSE RIBBON.

Harrison<sup>26</sup> states that this cane, which is cultivated with success in Australia, is identical with the striped sport appearing

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\* This sport was first grown on Hawaii by Mr. John Watt, who planted a number of the yellow shoots appearing in a small area of Striped Tip.

not infrequently in stools of Bourbon cane, and to which we refer more fully elsewhere. As synonyms<sup>20</sup> he gives Green Ribbon, Malay, Brisbane, White Striped Bourbon.

### THE UBA CANE.

Of late years a cane under this name has been frequently mentioned, and is stated to be cultivated with success in Madeira and in Natal. We have found the following early references to this cane.

It was introduced into Mauritius in 1869 from Brazil, and is described as a worthless cane.<sup>12</sup>

John Dymond states that the Uba cane, introduced into Louisiana from Brazil, is evidently the same as the Zwinga, or Japanese cane,<sup>24</sup> it is described as a green woolly cane of great vitality, and evidently suited to a cold climate.

### DANIEL DUPONT.

Occasionally in the literature of the cane this name appears as synonymous with Striped Tanna or Big Ribbon. The Daniel Dupont we have at this Station is described below.

A small cane which, when freshly stripped, is characterized by a mottled green and pink coloration that on exposure turns to a green with small, brown or dirty red patches. The leaf is medium sized, light green and slightly mottled; the sheath has a purplish cast, and bears a light scattering of hairs. The eye is prominent and rounded; the internodes are convex, and bulge out slightly on the opposite side from the eye, and have little or no grooving. The ground tissue of the cane is pure white, and the rind soft, with a marked tendency to split.

The confusion of this cane with Striped Tanna is explained in the following quotation:<sup>25</sup> “. . . to the farmer on the Clarence River it is probable that the Striped Tanna will be Daniel Dupont for the rest of his days, because it was wrongly named so when first introduced.”

### SPORTS.

Any one who has had to do with striped canes must have observed their tendency to throw a light colored and a dark colored sport; this tendency was some few years ago discussed at some length in the West Indian Bulletin, Vol. II, No. 4, where it is stated that a white sport obtained in Barbados from the “Red Ribbon” was undistinguishable from the “Burke,” and on the

authority of Mr. James Clarke of North Queensland that a white sport from Striped Singapore was to all intents and purposes identical with Rappoh.

A previous instance of this sporting habit is recorded by Melmoth Hall,<sup>26</sup> who thus writes: "I have, in one instance, seen no less than three distinct canes from one stool of the ribbon variety—one entirely yellow, another entirely green, the others being the usual ribbon canes; from other stools in the same field I found canes either of a uniform green purple or purplish brown, all the rest springing from the same ribbon root being striped in the customary way. The cuttings from the sports perpetuate the variety, and have usually some distinctive properties, such as rapidity of growth, or sweetness of juice, notably so in the case of the yellow cane."

We think it possible that this tendency to sport is a fact of no recent discovery, and that it has probably been known, though not written about, for many years, and from Wray's original term "Transparent" applied to the striped cane we trace the terms "White Transparent" and "Purple Transparent," and with the "Striped Bamboo" connect the names "Rose Bamboo" and "Dark Colored Bamboo"; in a similar way, in Java, the same name "Cheribon" has been applied to three canes with the distinguishing prefix of "White," "Black" and "Striped."

An exactly analogous instance is afforded in the three Tanna canes, the light colored variety of which, known in these islands as Yellow Caledonia, in Mauritius as White Tanna, and in Fiji as Malabar, is now one of the more important standard varieties. At one time it was supposed that it was only striped canes that threw sports, but this is now known to be incorrect; for instance, Harrison is responsible for the following statement:<sup>27</sup> "Recent observations in our experimental fields have shown that the green canes with a cream colored or yellowish stripe, alluded to on p. 41 of my last report, are sports from the Bourbon, and that therefore the old Barbados name of 'Striped Bourbon' or 'White Striped Bourbon' is the one properly applicable to them." Also, a similar instance was observed at this Station during the reaping of the experimental plots in the early part of 1908; that such a phenomenon is frequent is a matter of common knowledge in Mauritius.

So far as our experience has gone each light colored sport from a striped cane and each dark colored sport is identical, but

the canes of the Yellow Otaheite type seem to have the faculty of throwing two distinct sports; one of these is the Light Striped Bourbon cane, referred to by Harrison, and the other is the Horne cane. In Mauritius the fact that the Louzier throws two types of sports is generally recognized, where both the green and yellow sport and the red and yellow sport (to which the name Horne has been given, after its first observer) are indifferently known as Louzier Rayée.

We think that this phenomenon is of considerable academic interest, as it is analogous to De Vries' classical observations in variation conducted with *Oenothera lamarckiana* where he observed that from the parent plant the same sports repeatedly appeared. A further instance of variation from a self colored cane has recently come to our notice, Mr. E. H. W. Broadbent, of Grove Farm Plantation, having forwarded to this Station a green and yellow striped cane originating from a stool of Yellow Caledonia, and this we have at the present time under cultivation; this instance is of peculiar interest, as we have here a case of variation from a striped cane to a self colored cane, and then back to a striped cane, but different from the parent striped cane.

From what has been written above it is clear that at least three of the principal cultivated varieties of cane, the White Tauna, or Yellow Caledonia, the Rose Bamboo, or White Transparent, and the Purple Transparent, Louisiana Purple or Black Cheribon, are bud sports from striped canes. So far as we are aware it has never been suggested that the Lahaina (Bourbon, Louzier, Otaheite, etc.) has a similar origin, but the following account of the origin of the Louzier in Mauritius, for which we are indebted to M. August Villele, goes very far to show that this cane has had its origin in this way. Mr. Villele in reply to a letter from one of us, gives the following information:

"M. Lavignac, a French gentleman resident in Mauritius in 1868 or 1869, introduced from New Caledonia into that colony the canes known as 'Branchu rayée,' 'Branchu blanche,' 'Mapou Striée,' 'Bois Rouge,' 'Tamarind,' and finally, the 'Mignonne,' a red and green striped cane. ". . . The Mignonne was planted at Ternay (Grand Port), on an estate belonging to M. Louzier, a progressive gentleman who benefitted this estate by his labors; he noticed that the Mignonne gave self colored light canes; these he cultivated, and to this variety was given the name Louzier."

## SUMMARY OF MORE IMPORTANT CANE NAMES MENTIONED.

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Below are collected in alphabetical order synonyms of the varieties treated of in the foregoing pages: a star indicates that confusion in regard to this name has arisen; bold type indicates the more generally known names of the canes; the places where the names are localized are given in parentheses.

### THE YELLOW OTAHEITE CANE OR CANES.

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Bamboo II, Batavian (Bourbon), **BOURBON** (West Indies), China II, Cuban, Keni Keni, LAHAINA (Hawaii), Leent, LOUZIER\* (Mauritius), Portii,\* Singapore,\* Yellow.

### THE CHERIBON OR WRAY'S BATAVIAN CANES.

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#### Striped Variety:

HOME RIBBON (Louisiana), Mauritius Ribbon (Queensland), Red Ribbon (British West Indies), San Salvador, Seete,\* Striped Bamboo, STRIPED CHERIBON (Java), Striped Louisiana (Hawaii), Striped Mexican, Striped Singapore, Transparent.

#### Light Colored Variety:

Blue, Caledonian Queen, CRYSTALLINA\* (Cuba), Green, Hope, La Pice, Le Sassier, Light Java, Mamuri, Mexican Bamboo, Mont Blanc, Naga B., Panachee, RAPPOH\* (Queensland), ROSE BAMBOO\* (Hawaii), Tibboo Mird, WHITE TRANSPARENT (British West Indies), Yellow Singapore, Yellow Violet.

#### Dark Colored Variety:

Belouquet (Mauritius), BLACK CHERIBON (Java), Black Java, LOUISIANA PURPLE (Hawaii), Meera,\* Moore's Purple, Otaheite,\* Purple Bamboo, Purple Mauritius, Purple Transparent (British West Indies), Purple Violet, Queensland Creole, Tabor Numa, TIBBOO ETAM (Eastern Asia).

### THE TANNA CANES.

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#### Striped Variety:

Big Ribbon (Hawaii), Daniel Dupont,\* Gingham, Maillard, Otaheite Ribbon, STRIPED TANNA (Mauritius).

Light Colored Variety:

Malabar (Fiji), Green Tanna, WHITE TANNA (Mauritius),  
YELLOW CALEDONIA (Hawaii).

Dark Colored Variety:

Black Tanna.

#### THE SALANGORE CANE.

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Chinese Cane (Bourbon), Pinang, SALANGORE, Tibboo Cap-  
por, Tibboo Beltong Berabou.

#### THE CAVENGERIE CANE.

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Altamattie, CAVENGERIE (Hawaii), Cheribon\* (Queens-  
land), Louzier\* (Brazil), PO-A-OLE (British West Indies),  
PORT MACKAY\* (Mauritius).



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*Enter*  
See 1650.10.12

DIVISION OF AGRICULTURE AND CHEMISTRY.

BULLETIN NO. 27

REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION



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Total Solids in Mill Products by the  
Refractometer.

---

BY S. S. PECK

---

HONOLULU, T. H.  
1908

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**REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
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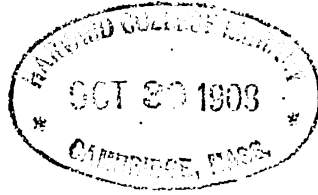
**Total Solids in Mill Products by the  
Refractometer.**

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**BY S. S. PECK.**

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**HONOLULU, HAWAII  
1908**



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## LETTER OF TRANSMITTAL.

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To the Experiment Station Committee of the  
Hawaiian Sugar Planters' Association,  
Honolulu, T. H.

Dear Sirs:—I herewith submit for publication as Bulletin No. 27 of the Division of Agriculture and Chemistry, an article by Mr. S. S. Peck, First Assistant Chemist, entitled "Total Solids in Mill Products by the Refractometer."

Yours very truly,

NOEL DEERR,

Acting Director, Division of Agriculture and Chemistry.

Honolulu, T. H., September 3, 1908.





# TOTAL SOLIDS IN MILL PRODUCTS BY THE REFRACTOMETER.

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BY S. S. PECK.

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## INTRODUCTION.

The inapplicability of the Brix spindle to the determination of the total solids of molasses, due to the varying specific gravities of the non-sugars, has been the subject of frequent contributions to sugar journals. For the determination of apparent purity, which suffices for the ordinary sugar-house control, the results are comparative and serviceable. But for the correct analysis of low grade products, which should include the sucrose by the Clerget process and the actual solids, other methods must be used. Drying on quartz sand or pumice stone at the temperature of boiling water at atmospheric or under reduced pressure has been the method usually employed, under various modifications. E. E. Hartmann<sup>1</sup> obtained satisfactory results by drying the molasses in a weighed test tube containing a thin roll of paper, diluted with a small quantity of water, and placed in boiling water while a current of dried air is drawn through. He considered the operation complete in two and a half hours. In a series of determinations of molasses, H. C. Prinsen-Geerligs obtained the dry matter by drying a weighed amount of a molasses of definite dilution on filter paper in a Scheibler dish at a temperature between 100° and 105° C. until constant weight was obtained. He had previously demonstrated<sup>2</sup> that it is the mineral matter which causes the greatest proportion of the discrepancy between Brix readings and true solids, but could find no fixed factor which could be applied to the former as a correction for the salts, to serve as a correction for true solid substance<sup>3</sup>; while several years previous to this<sup>4</sup> he had concluded that no relation exists between figures for Brix polarization, water, and purity. T. E. Halligan<sup>5</sup> conducted a series of determinations of the total solids in a molasses wherein he found that by drying the molasses for ten hours in a water oven at 98° he obtained results conforming very closely to the vacuum method. Prolonged drying produced results considerably lower. This was doubtless due to the con-

stant decomposition of certain lime compounds in the molasses, derived from the combination of lime with the invert sugar, or perhaps even of levulose alone. The high heat of drying is not necessary to effect this decomposition and liberation of gaseous compounds, such as formic or acetic acid. It is observable in the phenomenon known as "froth fermentation," frequently produced by over-liming or over-heating during latter boilings of molasses. E. C. Shorey<sup>6</sup> ascribed this to the decomposition of lime glycollate and J. Lely<sup>7</sup> to lime salts of glucinic acid, or the acid itself which decomposes above 65° C. into formic, acetic, and carbonic acid; but whatever the cause, the result is the same during the determination of solids in molasses by drying at too high temperature for any prolonged period, viz., the formation of gaseous decomposition compounds, and too low result as solid matter. This difficulty of a correct determination has been largely if not completely solved by the discovery of the applicability of the use of the refractometer for this purpose.

The refractive index of a substance is defined by Wiley<sup>8</sup> as "an expression to characterize the measurement of the degree of deflection caused in a ray of light in passing from one transparent medium into another." The instruments used for this purpose are called refractometers, and heretofore have been mainly used as one means of identifying or detecting the sophistication of oils, butter, lard, etc. The two principal instruments are those designed by Abbe and Pulfrich. These register the refractive indices of the substances under examination; but modifications, such as the oleorefractometer and butyrefractometer, are made with arbitrary scales adjusted to the measurements of oils or butters. It is not improbable if the refractometer finds an extended application in the sugar laboratories, that instruments will be made that will render reference to tables unnecessary, but will give readings of total solids directly on the scale; just as the polariscope today gives direct sugar percentages instead of degrees of optical rotation.

Of the two refractometers, the Abbe and Pulfrich, the former is more convenient, inasmuch as in the latter it is necessary to read by the yellow or sodium light, whereas in the latter, ordinary white light or that of a lamp can be used. The first reference we find to work in this direction is that by Tolman and Smith.<sup>9</sup> Their work was undertaken to test the value and accuracy of the Abbe refractometer for the estimation of sugars, to check up Stolle's<sup>10</sup> work on sugars, made with a Pulfrich instrument, and to carry the research into sugars not treated by him. They show that sucrose and glucose have the same index of refraction from

1 to 90%, while other sugars, with which we are not concerned, differ only very slightly.

The first practical application of the Abbe refractometer was made by Hugh Main<sup>11</sup> who found in this instrument a most satisfactory substitute for the determination of water in refinery syrups for the usual slow and unsatisfactory methods of drying in sand, etc. He also prepared a table for the refractive indices of sugar solution at 20° C. which is practically identical with that of Tolman and Smith, showing the absolute reliability of the instrument in this respect.

The further extension of the use of the refractometer to more impure solutions has been more recently demonstrated by Prinsen-Geerligs.<sup>12</sup> This writer first determined a table of the refractive indices of sugar solutions at a temperature of 28°, which is more suitable for tropical conditions, together with a table of corrections, which are reproduced in tables I and II, the figures in the first table having been figured for each division on the refractometer scale to the fourth decimal place by the writer. He then applied these figures to solutions of the various non-sugars occurring in molasses and found that sodium salts have almost the same indices, calcium salts higher, and salts of potash lower than that of sucrose. He then shows that in mixtures of a syrup of known composition, containing sucrose, glucose, and fructose in about the same proportion as exists in molasses, with sodium, potassium, and calcium glucinates (glucose decomposition products) the refractive index gave results approximating very closely to actual dry substance. A mixture of the syrup with the residue from fermentation and distillation of molasses, gave equally satisfactory results. Mr. Prinsen-Geerligs then gives some highly interesting figures from actual determinations of various mill products and remarks that "the method of dessication is not beyond suspicion for molasses and products containing much glucose, and is apt to give wrong figures, because of the retention of moisture by the viscous fluid as well as on account of the driving off of products of decomposition by the prolonged heating. If there is a difference between the figure for dry substance by the refractometer and by dessication, we are not at all sure that the latter figure is the correct one."

#### MOLASSES.

Twenty-five samples of waste or final molasses were examined by this Station for the purpose of comparing results obtained by dessication and the refractometer. The total solids were deter-

mined by drying for a period not greater than four hours in a water jacketed oven, under a vacuum of 20 inches and at 100° C. For this purpose flat dishes were covered with quartz sand which had been washed in acid, to a depth of about 5 mm. These were ignited, and weighed, with a small, dry stirring rod. About two grams of molasses were used in each determination, being dissolved in the smallest possible quantity of distilled water. Drying was usually complete in two hours, and always in four. Concordantly with these determinations, the refractive index was observed, and total solids calculated from Prinsen-Geerlig's tables. The results are given in the following table:

SOLIDS IN FINAL MOLASSES BY DRYING AND FROM REFRACTOMETER.

	Refract. Index.	Temp.	Solids from Table.	Solids by Dessication.	Difference.
1	1.4935	27.5°	81.76	81.99	— .23
2	1.4975	28.0°	83.35	83.47	— .12
3	1.4986	28.0°	83.75	81.94	+1.81
4	1.4998	27.0°	84.15	83.77	+ .38
5	1.4719	27.0°	73.22	71.67	+1.55
6	1.4886	27.5°	79.86	79.20	+ .66
7	1.4976	27.5°	83.36	83.45	— .09
8	1.4943	27.5°	82.06	82.46	— .40
9	1.4957	28.0°	82.63	82.04	+ .59
10	1.4877	27.5°	79.51	79.62	— .11
11	1.4979	28.0°	83.50	82.32	+1.18
12	1.5015	30.0°	85.00	86.16	—1.16
13	1.4953	28.0°	82.50	82.03	+ .47
14	1.5046	28.0°	86.00	85.40	+ .60
15	1.4942	27.5°	82.01	82.66	— .65
16	1.4971	28.0°	83.20	82.00	+1.20
17	1.4992	28.0°	84.00	84.30	— .30
18	1.5068	29.0°	86.91	86.02	+ .89
19	1.4926	28.0°	81.45	81.32	+ .13
20	1.5018	28.0°	84.95	86.63	—1.28
21	1.4947	28.5°	82.29	82.51	— .22
22	1.4970	30.0°	83.30	84.05	— .75
23	1.4875	28.0°	79.50	79.56	— .06
24	1.4973	27.5°	83.21	83.18	+ .03
25	1.5006	28.0°	84.53	84.47	+ .06
Average			82.64	84.49	+ .15

The refractometer used was an Abbe refractometer made by Zeiss, with heatable prisms. The refractive index for water at 28° was 1.3320. The temperature was kept constant by circulating water, held in a bottle with tubular side-opening, through the refractometer to a large vessel, whence it was dipped back to the bottle. The slight variations noted in temperature were due to the changing temperature of the laboratory. The instrument was placed near a door with a southern exposure, and with purer solutions gave a well defined shade that could be read on repeated trials by the same or different observers to the same place on the scale. With the molasses the shadow was considerably obscured, and it was only after considerable practice in reading and adjusting the eye-piece that concordant results could be obtained. When the image is too obscure, or when the molasses is seen to contain any considerable quantity of crystals, due either to false grain or a break in the centrifugal gauze, it is necessary to resort to dilution. Diluting the sample in nickel dishes with a large surface area did not give very satisfactory results, due to uncertainty as to when solution was completely effected, and difficulty in preventing evaporation during weighing. It was found better to weigh the molasses in tared flasks with necks of small diameter, dissolving completely with hot water, and after cooling and weighing, determining the refractive index. No attempt was made to get any precise dilution, but the percentage determined from the weights before and after the addition of water. Two samples of molasses gave the following results:

	No. 12.	No. 20.
Total solids, drying .....	86.16	86.63
Total solids, refractometer .....	85.00	84.95
Total solids, from diluted solution, drying.	86.51	—
Total solids, from diluted solution, refractometer .....	85.60	87.83

Molasses No. 20 contained a considerable quantity of grain: the refractometer would naturally give too low a figure for total solids in such an instance, when the observation is made without dilution.

#### THIN JUICES AND SYRUP.

Through the kindness of two of the Oahu plantations, a comparison of refractometer determinations of total solids in the various juices with those made by the usual instrument, the Brix

spindle, was made at the mills. In one mill there was found a record of comparisons made between total solids by spindling and by the drying of these juices. In the following tables we give in addition to the total solids by the Brix spindle and refractometer, the average figures obtained by the chemist of the mill by dessication, with the average Brix from the same juices. These averages, taken from juices analyzed at an entirely different period, approach very closely to the differences between the average Brix readings and the corresponding averages from the refractometer.

	Total Solids, Refractometer	Total Solids, Brix.	Difference.
Crusher Juice	19.17	19.42	— .25
	20.89	21.15	— .26
	21.23	21.32	— .09
	20.42	20.71	— .29
	21.67	21.83	— .16
	21.12	21.27	— .13
	—	—	—
Average	20.75	20.95	— .20
Average by drying*	20.45	20.89	— .44
Third Mill Juice	4.64	4.93	— .29
	5.85	5.93	— .08
	6.99	7.02	— .03
	6.79	6.59	+ .20
	6.79	6.28	+ .51
	—	—	—
Average	6.21	6.15	+ .06
Average by drying*	5.83	5.96	— .13
Fourth Mill Juice	3.34	3.68	— .34
	4.07	3.46	+ .61
	3.94	4.67	— .73
	4.54	4.80	— .26
	5.24	5.05	+ .19
	4.24	4.52	— .28
	—	—	—
Average	4.23	4.36	— .13
Average by drying*	3.23	3.36	— .13

\* Average of three determinations.

	Total Solids, Refractometer.	Total Solids, Brix.	Difference.
Mixed Juice	14.82	15.16	— .34
	16.30	16.33	— .03
	16.77	16.93	— .16
	16.82	17.27	— .45
	17.72	17.78	— .06
	15.97	16.11	— .14
	—	—	—
Average	16.40	16.59	— .19
Average by drying*	14.24	14.63	— .39
Clarified Juice	15.12	15.35	— .23
	15.33	15.53	— .23
	16.92	16.98	— .06
	17.32	17.62	— .30
	17.22	17.33	— .11
	16.82	17.00	— .18
	—	—	—
Average	16.46	16.64	— .18
Average by drying†	14.48	15.01	— .53
Press Juice	9.98	10.03	— .05
	7.78	7.81	— .03
	11.18	11.21	— .03
	12.18	12.50	— .32
	11.73	11.76	— .03
	12.38	12.53	— .15
	—	—	—
Average	10.87	10.97	— .10
Average by drying‡	9.26	9.39	— .13
Syrup	59.79	61.30	— 1.51
	63.09	63.66	— .57
	65.19	66.20	— 1.01
	66.09	67.32	— 1.23
	65.19	66.70	— 1.51
	65.84	67.20	— 1.36
	—	—	—
Average	64.20	65.40	— 1.20
Average by drying*	63.38	64.10	— .72

\* Average of six determinations.

† Average of four determinations.

‡ Average of five determinations.



In some instances, the determinations show considerable variation, particularly with the third and fourth mill juices, where plus differences, for some unaccountable reason, appear. However, the brix determinations of these juices are uncertain factors, due particularly to the large amount of air in the samples and the difficulty of a precise reading owing to the foam on the surface when in the cylinder. The refractometer readings, on the contrary, are not affected by such causes. The samples, after being cooled to room temperature, were filtered in a covered funnel, and after a few drops had passed through, a couple of drops were placed on the refractometer glass and the reading taken. It was observed that considerable care was necessary to prevent concentration due to evaporation, even syrup of 66 Brix showing considerable differences in the refractive indices after being allowed to stand in uncovered vessels for brief periods.

The large difference between the solids in syrup determined by the two methods was very surprising, considering that they were of equal purities with the clarified juices, and it should therefore be expected that equally concordant results would be obtained. For a more exact determination, a sample of syrup was brought to the Station laboratory. This had a refractive index of 1.4183 at 27°, equivalent to 63.32% total solids. By dessication the percentage was 63.26%, while the Brix, obtained from the specific gravity by pycometer, was 63.76%, showing a difference of —.44% by the refractometer.

The third and fourth mill juices were tried at the mill with the pycometer and the brix calculated therefrom. The average of the differences in two trials will be seen from the following table to approach very closely to those obtained by drying:

	Total Solids, Refractometer.	Brix from Specific Gravity.	Difference.
Third Mill Juice	6.59	6.80	— .21
	5.14	5.20	— .06
Average	....	....	— .14
Fourth Mill Juice	3.79	4.22	— .43
	3.14	3.16	— .02
Average	....	....	— .22

## RESIDUAL JUICE.

Attempts were made to determine the total solids in the residual juice, but the following table of solids in the diffused liquor shows that the results were widely divergent from those obtained with the pykometer::

Refractometer.	Pyknometer.	Difference.
.95	.64	+.31
.64	.60	+.04
.54	.66	-.12
.54	.59	-.05
.54	.62	-.08
.64	.50	+.14
.69	.59	+.10

In addition to the unsatisfactory nature of these results, a further objection to the use of the refractometer in this determination is the large difference in purity resulting from a small difference in the fourth decimal place. The scale on the instrument is graduated to the third decimal place, the fourth being interpolated, and as the divisions are not very large, a difference of one can possibly be made by two different observers. With a diffused liquor containing, say .33% sucrose, such a difference would mean a variation of fully five degrees in purity. It seems safe to conclude that under the present method of determining solids in the residual juice in the bagasse, the refractometer finds no place.

## MASSECUITES.

Two samples of massecuite were supplied by this mill and brought to the laboratory for determination of solids. These samples were very closely boiled and showed a brix of about 96 to 97 by the usual mill laboratory method of dilution and spindling. In determining the refractive indices, the procedure followed was to weigh out about 20 grams in a tared beaker, dissolve perfectly in hot water, transfer to a 50 cc. stoppered tared flask, cool, weigh, and determine the refractive index. The results from the No. 1 and No. 2 massecuites follow:

Masse-	Brix	Total Solids		
cuite.	Pyknometer.	Refractometer.	Dessication.	Difference.
1	95.04	93.02	93.22	— .20
2	97.42	94.05	93.91	+ .14

The results are entirely satisfactory, and while extreme care is necessary to effect perfect solution and to make accurate weighings, this is justified by the great saving of time in making the determinations and the perfect confidence to be felt in their accuracy.

#### CONTROL OF BOILING TO STRING PROOF.

A test was then made of the application of the instrument to controlling the concentration to a definite density, when boiling to string proof. For this purpose, the refractometer was installed on the pan floor and a convenient arrangement for carrying water through the prisms secured. An hour after the complement of No. 3 molasses was drawn in, (a full strike was not made, as there was not sufficient molasses on hand), when boiling down had commenced, samples were taken from the proof stick and rapidly placed on the prism of the instrument. A couple of minutes were allowed to let the prisms reach the temperature of the circulating water, and the reading taken. The following table gives the complete data obtained:

Time.	Refractive Index.	Temperature.	Total Solids.
1:35	1.4937	27°	81.77
1:45	1.4968	28°	83.05
1:55	1.4982	28°	83.60
2:05	1.4992	30°	84.15
2:15	1.5013	30°	84.95
2:25	1.5030	31°	85.63
2:35	1.5050	31°	86.38
2:45	1.5055	31°	86.56

The pan was struck as the last sample was taken. Samples from the cooler cars and tanks showed the No. 3 and No. 4 massecuites from previous strikes to have total solids of 86.35 and

85.20%, respectively. The last figure is not very far from that found in the observed strike, especially when we consider that it is possible that some grain had already separated from the magma.

It is suggested that the refractometer would be a very effectual instrument to use in controlling the boiling of low grade products. By keeping a complete record of a series of boilings of different purities and their yields, each mill could learn the optimum extent to which concentration should be carried, and more definite results would be achieved. No precise figures could be given for every mill on account of the varying nature not only of the molasses due to the character of the juices, methods of clarification and subsequent treatment of the juices, but also on account of differences in pans and storage facilities.

Boiling to a definite percentage of solids in the massecuite is possible by the use of the Brasmoscope, which depends on the accurate measurement of the temperature of the boiling mass and of the pressure in the pan. The use and application of this instrument, with the necessary table, has been fully described by Noël Deerr in a previous bulletin of this Station.<sup>13</sup> While this instrument is perhaps superior to the refractometer in that it can be used when boiling to grain, it has the disadvantages of the necessity of placing attachments on the pan itself, and the need of precise thermometric and barometric readings. The refractometer is an effectual substitute when boiling to string-proof, and not as difficult of application. Placed conveniently on a pan floor with a good light and connection with running water, it offers no difficulties to use by even the most inexperienced hands; and with proper and adequate care as regards cleanliness, it will last indefinitely.

#### CORRECTING BRIX SPINDLES.

The refractometer offers a rapid and convenient method for checking the correctness of the graduations on Brix spindles. This laboratory has recently had occasion to examine several spindles. The method employed was to take a solution of granulated sugar, bring it to the temperature at which the instrument was graduated (in this instance  $27.5^{\circ}$  C.), take the reading on the spindle, and then find the correct sucrose content by polarization. On this occasion, in addition to the polarimetric determination, the refractive indices were found, and the sucrose calculated from Prinsen-Geerligs' table.

The results by polariscope and refractometer were as follows:

Polariscope.	Refractometer.
2.0	2.05
4.6	4.60
12.8	12.85
19.2	19.20
23.8	23.85
32.0	32.10
39.1	39.20
41.6	41.70
45.7	45.80
53.2	53.15
58.8	58.90

In conclusion, the writer desires to express his obligation to the management and mill staffs of the Waialua Agricultural Company and Ewa Plantation Company for their courtesies and assistance in carrying out the investigations in their respective mills.

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TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.

(H. C. PRINSEN GEERLIGS.)

Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.
		1.3390	4.70	1.3450	8.70	1.3510	12.65
		91	4.80	51	8.80	11	12.70
		92	4.85	52	8.85	12	12.75
		93	4.90	53	8.90	13	12.80
		94	5.00	54	9.00	14	12.85
1.3335	1.00	95	5.05	55	9.05	15	12.90
36	1.05	96	5.10	56	9.10	16	13.00
37	1.10	97	5.20	57	9.20	17	13.10
38	1.20	98	5.25	58	9.25	18	13.20
39	1.30	99	5.30	59	9.30	19	13.25
1.3340	1.35	1.3400	5.40	1.3460	9.40	1.3520	13.30
41	1.40	01	5.45	61	9.45	21	13.40
42	1.50	02	5.50	62	9.50	22	13.45
43	1.60	03	5.60	63	9.60	23	13.50
44	1.65	04	5.65	64	9.65	24	13.60
45	1.70	05	5.70	65	9.70	25	13.65
46	1.80	06	5.80	66	9.80	26	13.70
47	1.85	07	5.85	67	9.85	27	13.80
48	1.90	08	5.90	68	9.90	28	13.85
49	2.00	09	6.00	69	10.00	29	13.90
1.3350	2.05	1.3410	6.05	1.3470	10.05	1.3530	14.00
51	2.10	11	6.10	71	10.10	31	14.05
52	2.20	12	6.20	72	10.20	32	14.10
53	2.25	13	6.25	73	10.25	33	14.20
54	2.30	14	6.30	74	10.30	34	14.25
55	2.40	15	6.40	75	10.40	35	14.30
56	2.45	16	6.45	76	10.45	36	14.40
57	2.50	17	6.50	77	10.50	37	14.45
58	2.60	18	6.60	78	10.60	38	14.50
59	2.65	19	6.65	79	10.65	39	14.60
1.3360	2.70	1.3420	6.70	1.3480	10.70	1.3540	14.65
61	2.80	21	6.80	81	10.80	41	14.70
62	2.85	22	6.85	82	10.85	42	14.80
63	2.90	23	6.90	83	10.90	43	14.85
64	3.00	24	7.00	84	11.00	44	14.90
65	3.05	25	7.05	85	11.05	45	14.95
66	3.10	26	7.10	86	11.10	46	15.00
67	3.20	27	7.20	87	11.20	47	15.05
68	3.25	28	7.25	88	11.25	48	15.10
69	3.30	29	7.30	89	11.30	49	15.20
1.3370	3.40	1.3430	7.40	1.3490	11.40	1.3550	15.25
71	3.45	31	7.45	91	11.45	51	15.30
72	3.50	32	7.50	92	11.50	52	15.40
73	3.60	33	7.60	93	11.60	53	15.45
74	3.65	34	7.65	94	11.65	54	15.50
75	3.70	35	7.70	95	11.70	55	15.60
76	3.80	36	7.80	96	11.75	56	15.65
77	3.85	37	7.85	97	11.80	57	15.70
78	3.90	38	7.90	98	11.85	58	15.75
79	4.00	39	8.00	99	11.90	59	15.80
1.3380	4.05	1.3440	8.05	1.3500	12.00	1.3560	15.85
81	4.10	41	8.10	01	12.05	61	15.90
82	4.20	42	8.20	02	12.10	62	16.00
83	4.25	43	8.25	03	12.20	63	16.05
84	4.30	44	8.30	04	12.25	64	16.10
85	4.40	45	8.40	05	12.30	65	16.20
86	4.45	46	8.45	06	12.40	66	16.25
87	4.50	47	8.50	07	12.45	67	16.30
88	4.60	48	8.60	08	12.50	68	16.40
89	4.65	49	8.65	09	12.60	69	16.45

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.

(Continued.)

Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.
<b>1.3570</b>	16.50	<b>1.3630</b>	20.15	<b>1.3690</b>	23.70	<b>1.3750</b>	27.20
71	16.60	31	20.20	91	23.80	51	27.30
72	16.65	32	20.30	92	23.85	52	27.35
73	16.70	33	20.35	93	23.90	53	27.40
74	16.75	34	20.40	94	23.95	54	27.45
75	16.80	35	20.45	95	24.00	55	27.50
76	16.85	36	20.50	96	24.05	56	27.60
77	16.90	37	20.60	97	24.10	57	27.65
78	17.00	38	20.65	98	24.15	58	27.70
79	17.05	39	20.70	99	24.20	59	27.75
<b>1.3580</b>	17.10	<b>1.3640</b>	20.80	<b>1.3700</b>	24.30	<b>1.3760</b>	27.80
81	17.20	41	20.85	01	24.35	61	27.85
82	17.25	42	20.90	02	24.40	62	27.90
83	17.30	43	20.95	03	24.45	63	27.95
84	17.40	44	21.00	04	24.50	64	28.00
85	17.45	45	21.05	05	24.60	65	28.05
86	17.50	46	21.10	06	24.65	66	28.10
87	17.60	47	21.15	07	24.70	67	28.15
88	17.65	48	21.20	08	24.80	68	28.20
89	17.70	49	21.30	09	24.85	69	28.30
<b>1.3590</b>	17.75	<b>1.3650</b>	21.35	<b>1.3710</b>	24.90	<b>1.3770</b>	28.35
91	17.80	51	21.40	11	24.95	71	28.40
92	17.85	52	21.45	12	25.00	72	28.45
93	17.90	53	21.50	13	25.05	73	28.50
94	18.00	54	21.60	14	25.10	74	28.60
95	18.05	55	21.65	15	25.15	75	28.65
96	18.10	56	21.70	16	25.20	76	28.70
97	18.15	57	21.80	17	25.30	77	28.75
98	18.20	58	21.85	18	25.35	78	28.80
99	18.30	59	21.90	19	25.40	79	28.85
<b>1.3600</b>	18.35	<b>1.3660</b>	21.95	<b>1.3720</b>	25.45	<b>1.3780</b>	28.90
01	18.40	61	22.00	21	25.50	81	28.95
02	18.45	62	22.05	22	25.60	82	29.00
03	18.50	63	22.10	23	25.65	83	29.05
04	18.60	64	22.15	24	25.70	84	29.10
05	18.65	65	22.20	25	25.80	85	29.15
06	18.70	66	22.30	26	25.85	86	29.20
07	18.80	67	22.35	27	25.90	87	29.30
08	18.85	68	22.40	28	25.95	88	29.35
09	18.90	69	22.45	29	26.00	89	29.40
<b>1.3610</b>	18.95	<b>1.3670</b>	22.50	<b>1.3730</b>	26.05	<b>1.3790</b>	29.45
11	19.00	71	22.60	31	26.10	91	29.50
12	19.05	72	22.65	32	26.15	92	29.60
13	19.10	73	22.70	33	26.20	93	29.65
14	19.20	74	22.80	34	26.30	94	29.70
15	19.25	75	22.85	35	26.35	95	29.75
16	19.30	76	22.90	36	26.40	96	29.80
17	19.40	77	22.95	37	26.45	97	29.85
18	19.45	78	23.00	38	26.50	98	29.90
19	19.50	79	23.05	39	26.60	99	29.95
<b>1.3620</b>	19.60	<b>1.3680</b>	23.10	<b>1.3740</b>	26.65	<b>1.3800</b>	30.00
21	19.65	81	23.15	41	26.80	01	30.05
22	19.70	82	23.20	42	26.85	02	30.10
23	19.75	83	23.30	43	26.90	03	30.15
24	19.80	84	23.35	44	26.95	04	30.20
25	19.85	85	23.40	45	27.00	05	30.30
26	19.90	86	23.45	46	27.05	06	30.35
27	20.00	87	23.50	47	27.10	07	30.40
28	20.05	88	23.60	48	27.15	08	30.45
29	20.10	89	23.65	49	27.20	09	30.50

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.

(Continued.)

Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.
1.3810	30.55	1.3870	33.90	1.3930	37.10	1.3990	40.30
11	30.60	71	33.95	31	37.15	91	40.35
12	30.65	72	34.00	32	37.20	92	40.40
13	30.70	73	34.05	33	37.25	93	40.45
14	30.75	74	34.10	34	37.30	94	40.50
15	30.80	75	34.15	35	37.35	95	40.60
16	30.85	76	34.20	36	37.40	96	40.65
17	30.90	77	34.30	37	37.45	97	40.70
18	30.95	78	34.35	38	37.50	98	40.75
19	31.00	79	34.40	39	37.60	99	40.80
	31.05						
1.3820	31.10	1.3880	34.45	1.3940	37.65	1.4000	40.85
21	31.15	81	34.50	41	37.70	01	40.90
22	31.20	82	34.55	42	37.75	02	40.95
23	31.25	83	34.60	43	37.80	03	41.00
24	31.30	84	34.65	44	37.85	04	41.05
25	31.35	85	34.70	45	37.90	05	41.10
26	31.40	86	34.80	46	37.95	06	41.15
27	31.45	87	34.85	47	38.00	07	41.20
28	31.50	88	34.90	48	38.05	08	41.25
29	31.55	89	34.95	49	38.10	09	41.30
	31.60						
1.3830	31.65	1.3890	35.00	1.3950	38.15	1.4010	41.35
31	31.70	91	35.05	51	38.20	11	41.40
32	31.75	92	35.10	52	38.25	12	41.45
33	31.80	93	35.15	53	38.30	13	41.50
34	31.85	94	35.20	54	38.35	14	41.55
35	31.90	95	35.25	55	38.40	15	41.60
36	31.95	96	35.30	56	38.45	16	41.65
37	32.00	97	35.35	57	38.50	17	41.70
38	32.05	98	35.40	58	38.60	18	41.75
39	32.10	99	35.45	59	38.65	19	41.80
	32.15						
1.3840	32.20	1.3900	35.50	1.3960	38.70	1.4020	41.85
41	32.25	01	35.60	61	38.75	21	41.90
42	32.30	02	35.65	62	38.80	22	41.95
43	32.35	03	35.70	63	38.85	23	42.00
44	32.40	04	35.75	64	38.90	24	42.05
45	32.45	05	35.80	65	38.95	25	42.10
46	32.50	06	35.85	66	39.00	26	42.15
47	32.55	07	35.90	67	39.05	27	42.20
48	32.60	08	35.95	68	39.10	28	42.25
49	32.65	09	36.00	69	39.15	29	42.30
	32.70						
1.3850	32.75	1.3910	36.05	1.3970	39.20	1.4030	42.35
51	32.80	11	36.10	71	39.30	31	42.40
52	32.85	12	36.15	72	39.35	32	42.45
53	32.90	13	36.20	73	39.40	33	42.50
54	32.95	14	36.25	74	39.45	34	42.55
55	33.00	15	36.30	75	39.50	35	42.60
56	33.05	16	36.35	76	39.55	36	42.65
57	33.10	17	36.40	77	39.60	37	42.70
58	33.15	18	36.45	78	39.65	38	42.75
59	33.20	19	36.50	79	39.70	39	42.80
	33.25						
1.3860	33.30	1.3920	36.60	1.3980	39.80	1.4040	42.85
61	33.35	21	36.65	81	39.85	41	42.90
62	33.40	22	36.70	82	39.90	42	42.95
63	33.45	23	36.75	83	39.95	43	43.00
64	33.50	24	36.80	84	40.00	44	43.05
65	33.55	25	36.85	85	40.05	45	43.10
66	33.60	26	36.90	86	40.10	46	43.15
67	33.65	27	36.95	87	40.15	47	43.20
68	33.70	28	37.00	88	40.20	48	43.25
69	33.75	29	37.05	89	40.25	49	43.30



TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.

(Continued.)

Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.
1.4050	43.35	1.4110	46.30	1.4170	49.20	1.4230	52.10
51	43.40	11	46.35	71	49.25	31	52.15
52	43.45	12	46.40	72	49.30	32	52.20
53	43.50	13	46.45	73	49.35	33	52.25
54	43.55	14	46.50	74	49.40	34	52.30
55	43.60	15	46.55	75	49.45	35	52.35
56	43.65	16	46.60	76	49.50	36	52.40
57	43.70	17	46.65	77	49.55	37	52.45
58	43.75	18	46.70	78	49.60	38	52.50
59	43.80	19	46.75	79	49.65	39	52.53
1.4060	43.85	1.4120	46.80	1.4180	49.70	1.4240	52.55
61	43.90	21	46.85	81	49.75	41	52.60
62	43.95	22	46.90	82	49.80	42	52.65
63	44.00	23	46.95	83	49.85	43	52.70
64	44.05	24	47.00	84	49.90	44	52.75
65	44.10	25	47.05	85	49.95	45	52.80
66	44.15	26	47.10	86	50.00	46	52.85
67	44.20	27	47.15	87	50.05	47	52.90
68	44.25	28	47.20	88	50.10	48	52.95
69	44.30	29	47.25	89	50.15	49	53.00
1.4070	44.35	1.4130	47.30	1.4190	50.20	1.4250	53.05
71	44.40	31	47.35	91	50.25	51	53.10
72	44.45	32	47.40	92	50.30	52	53.15
73	44.50	33	47.45	93	50.35	53	53.20
74	44.55	34	47.50	94	50.40	54	53.25
75	44.60	35	47.53	95	50.45	55	53.30
76	44.65	36	47.55	96	50.50	56	53.35
77	44.70	37	47.60	97	50.53	57	53.40
78	44.75	38	47.65	98	50.55	58	53.45
79	44.80	39	47.70	99	50.60	59	53.50
1.4080	44.85	1.4140	47.75	1.4200	50.65	1.4260	53.53
81	44.90	41	47.80	01	50.70	61	53.55
82	44.95	42	47.85	02	50.75	62	53.60
83	45.00	43	47.90	03	50.80	63	53.65
84	45.05	44	47.95	04	50.85	64	53.70
85	45.10	45	48.00	05	50.90	65	53.75
86	45.15	46	48.05	06	50.95	66	53.80
87	45.20	47	48.10	07	51.00	67	53.85
88	45.25	48	48.15	08	51.05	68	53.90
89	45.30	49	48.20	09	51.10	69	53.95
1.4090	45.35	1.4150	48.25	1.4210	51.15	1.4270	54.00
91	45.40	51	48.30	11	51.20	71	54.05
92	45.45	52	48.35	12	51.25	72	54.10
93	45.50	53	48.40	13	51.30	73	54.15
94	45.53	54	48.45	14	51.35	74	54.20
95	45.55	55	48.50	15	51.40	75	54.23
96	45.60	56	48.53	16	51.45	76	54.25
97	45.65	57	48.55	17	51.50	77	54.30
98	45.70	58	48.60	18	51.53	78	54.35
99	45.75	59	48.65	19	51.55	79	54.40
1.4100	45.80	1.4160	48.70	1.4220	51.60	1.4280	54.45
01	45.85	61	48.75	21	51.65	81	54.50
02	45.90	62	48.80	22	51.70	82	54.55
03	45.95	63	48.85	23	51.75	83	54.60
04	46.00	64	48.90	24	51.80	84	54.65
05	46.05	65	48.95	25	51.85	85	54.70
06	46.10	66	49.00	26	51.90	86	54.73
07	46.15	67	49.05	27	51.95	87	54.75
08	46.20	68	49.10	28	52.00	88	54.80
09	46.25	69	49.15	29	52.05	89	54.85

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.

(Continued.)

Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.
1.4290	54.90	1.4350	57.60	1.4410	60.23	1.4470	62.83
91	54.95	51	57.65	11	60.25	71	62.85
92	55.00	52	57.70	12	60.30	72	62.90
93	55.05	53	57.73	13	60.35	73	62.95
94	55.10	54	57.75	14	60.40	74	63.00
95	55.15	55	57.80	15	60.45	75	63.05
96	55.20	56	57.85	16	60.50	76	63.10
97	55.23	57	57.90	17	60.53	77	63.15
98	55.25	58	57.95	18	60.55	78	63.20
99	55.30	59	58.00	19	60.60	79	63.23
1.4300	55.35	1.4360	58.05	1.4420	60.65	1.4480	63.25
01	55.40	61	58.10	21	60.70	81	63.30
02	55.45	62	58.15	22	60.75	82	63.35
03	55.50	63	58.20	23	60.80	83	63.40
04	55.55	64	58.23	24	60.83	84	63.45
05	55.60	65	58.25	25	60.85	85	63.50
06	55.65	66	58.30	26	60.90	86	63.53
07	55.70	67	58.35	27	60.95	87	63.55
08	55.73	68	58.40	28	61.00	88	63.60
09	55.75	69	58.45	29	61.05	89	63.65
1.4310	55.80	1.4370	58.50	1.4430	61.10	1.4490	63.70
11	55.85	71	58.53	31	61.15	91	63.75
12	55.90	72	58.55	32	61.20	92	63.80
13	55.95	73	58.60	33	61.23	93	63.83
14	56.00	74	58.65	34	61.25	94	63.85
15	56.05	75	58.70	35	61.30	95	63.90
16	56.10	76	58.75	36	61.35	96	63.95
17	56.15	77	58.80	37	61.40	97	64.00
18	56.20	78	58.83	38	61.45	98	64.05
19	56.23	79	58.85	39	61.50	99	64.10
1.4320	56.25	1.4380	58.90	1.4440	61.53	1.4500	64.15
21	56.30	81	58.95	41	61.55	01	64.20
22	56.35	82	59.00	42	61.60	02	64.23
23	56.40	83	59.05	43	61.65	03	64.25
24	56.45	84	59.10	44	61.70	04	64.30
25	56.50	85	59.15	45	61.75	05	64.35
26	56.55	86	59.20	46	61.80	06	64.40
27	56.60	87	59.23	47	61.83	07	64.45
28	56.65	88	59.25	48	61.85	08	64.50
29	56.70	89	59.30	49	61.90	09	64.53
1.4330	56.75	1.4390	59.35	1.4450	61.95	1.4510	64.55
31	56.80	91	59.40	51	62.00	11	64.60
32	56.85	92	59.45	52	62.05	12	64.65
33	56.90	93	59.50	53	62.10	13	64.70
34	56.95	94	59.53	54	62.15	14	64.75
35	57.00	95	59.55	55	62.20	15	64.80
36	57.05	96	59.60	56	62.23	16	64.83
37	57.10	97	59.65	57	62.25	17	64.85
38	57.15	98	59.70	58	62.30	18	64.90
39	57.20	99	59.75	59	62.35	19	64.95
1.4340	57.25	1.4400	59.80	1.4460	62.40	1.4520	65.00
41	57.30	01	59.83	61	62.45	21	65.05
42	57.35	02	59.85	62	62.50	22	65.10
43	57.40	03	59.90	63	62.53	23	65.15
44	57.45	04	59.95	64	62.55	24	65.20
45	57.50	05	60.00	65	62.60	25	65.23
46	57.55	06	60.05	66	62.65	26	65.25
47	57.60	07	60.10	67	62.70	27	65.30
48	57.65	08	60.15	68	62.75	28	65.35
49	57.70	09	60.20	69	62.80	29	65.40

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.

(Continued.)

Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.
1.4530	65.45	1.4590	67.95	1.4650	70.45	1.4710	72.95
31	65.50	91	68.00	51	70.50	11	73.00
32	65.53	92	68.05	52	70.55	12	73.03
33	65.55	93	68.10	53	70.60	13	73.05
34	65.60	94	68.15	54	70.63	14	73.10
35	65.65	95	68.20	55	70.65	15	73.15
36	65.70	96	68.23	56	70.70	16	73.20
37	65.75	97	68.25	57	70.75	17	73.23
38	65.80	98	68.30	58	70.80	18	73.25
39	65.83	99	68.35	59	70.83	19	73.30
1.4540	65.85	1.4600	68.40	1.4660	70.85	1.4720	73.35
41	65.90	01	68.43	61	70.90	21	73.40
42	65.95	02	68.45	62	70.95	22	73.43
43	66.00	03	68.50	63	71.00	23	73.45
44	66.05	04	68.55	64	71.05	24	73.50
45	66.10	05	68.60	65	71.10	25	73.55
46	66.15	06	68.63	66	71.15	26	73.60
47	66.20	07	68.65	67	71.20	27	73.63
48	66.23	08	68.70	68	71.23	28	73.65
49	66.25	09	68.75	69	71.25	29	73.70
1.4550	66.30	1.4610	68.80	1.4670	71.30	1.4730	73.75
51	66.35	11	68.83	71	71.35	31	73.80
52	66.40	12	68.85	72	71.40	32	73.83
53	66.43	13	68.90	73	71.43	33	73.85
54	66.45	14	68.95	74	71.45	34	73.90
55	66.50	15	69.00	75	71.50	35	73.95
56	66.55	16	69.05	76	71.55	36	74.00
57	66.60	17	69.10	77	71.60	37	74.03
58	66.63	18	69.15	78	71.63	38	74.05
59	66.65	19	69.20	79	71.65	39	74.10
1.4560	66.70	1.4620	69.23	1.4680	71.70	1.4740	74.15
61	66.75	21	69.25	81	71.75	41	74.20
62	66.80	22	69.30	82	71.80	42	74.23
63	66.83	23	69.35	83	71.83	43	74.25
64	66.85	24	69.40	84	71.85	44	74.30
65	66.90	25	69.43	85	71.90	45	74.35
66	66.95	26	69.45	86	71.95	46	74.40
67	67.00	27	69.50	87	72.00	47	74.43
68	67.05	28	69.55	88	72.05	48	74.45
69	67.10	29	69.60	89	72.10	49	74.50
1.4570	67.15	1.4630	69.63	1.4690	72.15	1.4750	74.55
71	67.20	31	69.65	91	72.20	51	74.60
72	67.23	32	69.70	92	72.23	52	74.63
73	67.25	33	69.75	93	72.25	53	74.65
74	67.30	34	69.80	94	72.30	54	74.70
75	67.35	35	69.83	95	72.35	55	74.75
76	67.40	36	69.85	96	72.40	56	74.80
77	67.43	37	69.90	97	72.43	57	74.83
78	67.45	38	69.95	98	72.45	58	74.85
79	67.50	39	70.00	99	72.50	59	74.90
1.4580	67.55	1.4640	70.05	1.4700	72.55	1.4760	74.95
81	67.60	41	70.10	01	72.60	61	75.00
82	67.63	42	70.15	02	72.63	62	75.03
83	67.65	43	70.20	03	72.65	63	75.05
84	67.70	44	70.23	04	72.70	64	75.10
85	67.75	45	70.25	05	72.75	65	75.15
86	67.80	46	70.30	06	72.80	66	75.20
87	67.83	47	70.35	07	72.83	67	75.23
88	67.85	48	70.40	08	72.85	68	75.25
89	67.90	49	70.43	09	72.90	69	75.30

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.

(Continued.)

Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.
1.4770	75.35	1.4830	77.75	1.4890	80.05	1.4950	82.40
71	75.40	31	77.80	91	80.10	51	82.43
72	75.43	32	77.83	92	80.15	52	82.45
73	75.45	33	77.85	93	80.20	53	82.50
74	75.50	34	77.90	94	80.23	54	82.53
75	75.55	35	77.95	95	80.25	55	82.55
76	75.60	36	78.00	96	80.30	56	82.60
77	75.63	37	78.03	97	80.35	57	82.63
78	75.65	38	78.05	98	80.40	58	82.65
79	75.70	39	78.10	99	80.43	59	82.70
1.4780	75.75	1.4840	78.15	1.4900	80.45	1.4960	82.75
81	75.80	41	78.20	01	80.50	61	82.80
82	75.83	42	78.23	02	80.53	62	82.83
83	75.85	43	78.25	03	80.55	63	82.85
84	75.90	44	78.30	04	80.60	64	82.90
85	75.95	45	78.35	05	80.63	65	82.95
86	76.00	46	78.40	06	80.65	66	83.00
87	76.03	47	78.43	07	80.70	67	83.03
88	76.05	48	78.45	08	80.75	68	83.05
89	76.10	49	78.50	09	80.80	69	83.10
1.4790	76.15	1.4850	78.53	1.4910	80.83	1.4970	83.15
91	76.20	51	78.55	11	80.85	71	83.20
92	76.23	52	78.60	12	80.90	72	83.23
93	76.25	53	78.63	13	80.95	73	83.25
94	76.30	54	78.65	14	81.00	74	83.30
95	76.35	55	78.70	15	81.03	75	83.35
96	76.40	56	78.75	16	81.05	76	83.40
97	76.43	57	78.80	17	81.10	77	83.43
98	76.45	58	78.83	18	81.15	78	83.45
99	76.50	59	78.85	19	81.20	79	83.50
1.4800	76.55	1.4860	78.90	1.4920	81.23	1.4980	83.53
01	76.60	21	78.95	21	81.25	81	83.55
02	76.63	22	79.00	22	81.30	82	83.60
03	76.65	23	79.03	23	81.35	83	83.63
04	76.70	24	79.05	24	81.40	84	83.65
05	76.75	25	79.10	25	81.43	85	83.70
06	76.80	26	79.15	26	81.45	86	83.75
07	76.83	27	79.20	27	81.50	87	83.80
08	76.85	28	79.23	28	81.53	88	83.83
09	76.90	29	79.25	29	81.55	89	83.85
1.4810	76.95	1.4870	79.30	1.4930	81.60	1.4990	83.90
11	77.00	71	79.35	31	81.63	91	83.95
12	77.03	72	79.40	32	81.65	92	84.00
13	77.05	73	79.43	33	81.70	93	84.03
14	77.10	74	79.45	34	81.75	94	84.05
15	77.15	75	79.50	35	81.80	95	84.10
16	77.20	76	79.53	36	81.83	96	84.15
17	77.23	77	79.55	37	81.85	97	84.20
18	77.25	78	79.60	38	81.90	98	84.23
19	77.30	79	79.63	39	81.95	99	84.25
1.4820	77.35	1.4880	79.65	1.4940	82.00	1.5000	84.30
21	77.40	81	79.70	41	82.03	01	84.33
22	77.43	82	79.75	42	82.05	02	84.35
23	77.45	83	79.80	43	82.10	03	84.40
24	77.50	84	79.83	44	82.15	04	84.45
25	77.55	85	79.85	45	82.20	05	84.50
26	77.60	86	79.90	46	82.23	06	84.53
27	77.63	87	79.95	47	82.25	07	84.55
28	77.65	88	80.00	48	82.30	08	84.60
29	77.70	89	80.03	49	82.35	09	84.63

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.

(Continued.)

Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.	Index.	Per Cent. Dry Sub- stance.
1.5010	84.65	1.5070	86.90	1.5130	89.10
11	84.70	71	86.93	31	89.13
12	84.75	72	86.95	32	89.15
13	84.80	73	87.00	33	89.20
14	84.83	74	87.03	34	89.23
15	84.85	75	87.05	35	89.25
16	84.90	76	87.10	36	89.30
17	84.93	77	87.15	37	89.35
18	84.95	78	87.20	38	89.40
19	85.00	79	87.23	39	89.43
1.5020	85.03	1.5080	87.25	1.5140	89.45
21	85.05	81	87.30	41	89.50
22	85.10	82	87.33	42	89.53
23	85.15	83	87.35	43	89.55
24	85.20	84	87.40	44	89.60
25	85.23	85	87.45	45	89.63
26	85.25	86	87.50	46	89.65
27	85.30	87	87.53	47	89.70
28	85.33	88	87.55	48	89.75
29	85.35	89	87.60	49	89.80
1.5030	85.40	1.5090	87.63	1.5150	89.83
31	85.45	91	87.65	51	89.85
32	85.50	92	87.70	52	89.90
33	85.53	93	87.75	53	89.93
34	85.55	94	87.80	54	89.95
35	85.60	95	87.83	55	90.00
36	85.63	96	87.85	56	90.03
37	85.65	97	87.90	57	90.05
38	85.70	98	87.93	58	90.10
39	85.75	99	87.95	59	90.13
1.5040	85.80	1.5100	88.00	1.5160	90.15
41	85.83	01	88.03	61	90.20
42	85.85	02	88.05	62	90.23
43	85.90	03	88.10	63	90.30
44	85.93	04	88.15	64	90.33
45	85.95	05	88.20	65	90.35
46	86.00	06	88.23	66	90.40
47	86.03	07	88.25	67	90.43
48	86.05	08	88.30	68	90.45
49	86.10	09	88.33	69	90.50
1.5050	86.15	1.5110	88.35	1.5170	90.53
51	86.20	11	88.40	71	90.55
52	86.23	12	88.45	72	90.60
53	86.25	13	88.50	73	90.63
54	86.30	14	88.53	74	90.65
55	86.33	15	88.55	75	90.70
56	86.35	16	88.60	76	90.75
57	86.40	17	88.63	77	90.80
58	86.45	18	88.65	78	90.83
59	86.50	19	88.70	79	90.85
1.5060	86.53	1.5120	88.75	1.5180	90.90
61	86.55	21	88.80	81	90.93
62	86.60	22	88.83	82	90.95
63	86.63	23	88.85		
64	86.65	24	88.90		
65	86.70	25	88.93		
66	86.75	26	88.95		
67	86.80	27	89.00		
68	86.83	28	89.03		
69	86.85	29	89.05		

TABLE OF CORRECTIONS FOR THE TEMPERATURE.

<i>Dry Substance.</i>														
Temperature of the Prisms in ° C.	0	5	10	15	20	25	30	40	50	60	70	80	90	
<i>Subtract.</i>														
20	.53	.54	.55	.56	.57	.58	.60	.62	.64	.62	.61	.60	.58	
21	.46	.47	.48	.49	.50	.51	.52	.54	.56	.54	.53	.52	.50	
22	.40	.41	.42	.42	.43	.44	.45	.47	.48	.47	.46	.45	.44	
23	.33	.33	.34	.35	.36	.37	.38	.39	.40	.39	.38	.38	.38	
24	.26	.26	.27	.28	.28	.29	.30	.31	.32	.31	.31	.30	.30	
25	.20	.20	.21	.21	.22	.22	.23	.23	.24	.23	.23	.23	.22	
26	.12	.12	.13	.14	.14	.14	.15	.15	.16	.16	.16	.15	.14	
27	.07	.07	.07	.07	.07	.07	.08	.08	.08	.08	.08	.08	.07	
<i>Add.</i>														
29	.07	.07	.07	.07	.07	.07	.08	.08	.08	.08	.08	.08	.07	
30	.12	.12	.13	.14	.14	.14	.15	.15	.16	.16	.16	.15	.14	
31	.20	.20	.21	.21	.22	.22	.23	.23	.24	.23	.23	.23	.22	
32	.26	.26	.27	.28	.28	.29	.30	.31	.32	.31	.31	.30	.30	
33	.33	.33	.34	.35	.36	.37	.38	.39	.40	.39	.38	.38	.38	
34	.40	.41	.42	.42	.43	.44	.45	.47	.48	.47	.46	.45	.44	
35	.46	.47	.48	.49	.50	.51	.52	.54	.56	.54	.53	.52	.50	











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**REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION**

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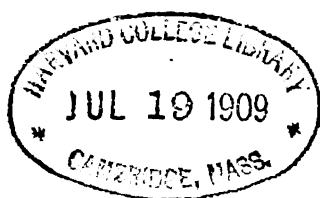
**Fermentation of Hawaiian Molasses.**

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**BY S. S. PECK AND NOËL DEERR**

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**HONOLULU, HAWAII  
APRIL, 1909**



## LETTER OF TRANSMITTAL.

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To the Experiment Station Committee of the  
Hawaiian Sugar Planters' Association,  
Honolulu, Hawaii.

Dear Sirs:

I herewith submit for publication, as Bulletin No. 28 of the Division of Agriculture and Chemistry, an article by Mr. S. S. Peck and Mr. Noël Deerr, entitled: "Fermentation of Hawaiian Molasses, with Descriptions of Yeasts Occurring in Tropical Distilleries."

Yours very truly,

C. F. ECKART,  
Director, Division of Agriculture and Chemistry.

Honolulu, T. H., April 22, 1909.



# FERMENTATION OF HAWAIIAN MOLASSES.

*With Descriptions of 'Yeasts Occurring in Tropical Distilleries.*

---

BY S. S. PECK AND NOËL DEERR.

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## INTRODUCTION.

The cane crop of 1908 in these islands produced something over 500,000 tons of sugar. From the figures of the annual synopsis of mill data<sup>1</sup> covering thirty-two factories, there was also produced about thirty gallons of molasses to each ton of commercial sugar, or a total, in all the factories, of fifteen million gallons. This by-product was disposed of in the usual manner, viz: feeding to stock, burning as fuel, conducted on to the land as fertilizer, or actually wasted and run into the sea. In only the first method of utilization does the molasses return its full economic value, since the results of numerous experiments with working horses, cattle, and other stock fully confirm the importance attached to this method of disposal. The carbohydrates are transformed into work and the fertilizing ingredients can be returned to the soil in the excreta of the animals. As a fuel, all of the nitrogen and part of the potash are lost as fertilizing elements, while many opinions as to its value in this respect are inclined more to condemn than recommend it. As a fertilizer, all of the contained sugars are lost; and it is probable that their presence in some soils, particularly those with poor drainage and low lime content, works more damage by fermentation and creation of unhealthy acidity, than the benefit derived from the potash and nitrogen contents can counterbalance.

In Mauritius, where decided benefits have followed the use of molasses as fertilizer, it would appear from an article by Ebbels<sup>2</sup> on this subject that the benefit due to their application is not entirely to be ascribed to the plant food therein, but to a beneficial action on certain soil bacteria, such as *Azotobacter chroococcum*. This organism has the property of fixing the nitrogen in the air, and is apparently stimulated in its action by the presence of carbohydrates, such as sugar. The writer points out that in order to use molasses to advantage, it appears to be necessary to spread the molasses over as large an area as possible and to work it into the upper layer of soil, and tentative experiments described



by him show a considerable fixation of nitrogen in the soil, presumably due to the action of *Azotobacter chroococcum*, influenced by the presence of the carbohydrates in molasses.

The amount of final molasses used as food is probably not more than a third of that produced. The animal census of 1907, in the year book of the United States Department of Agriculture, gives the following figures for the Hawaiian Islands:

Dairy cows .....	4,028
Horses .....	12,982
Mules .....	6,506
<hr/>	
Total .....	23,516

If each animal were fed six pounds of molasses per day, there would be consumed daily about 12,000 gallons of molasses, weighing twelve pounds to the gallon, or 4,380,000 gallons per year. There are, then, at least ten millions of gallons of molasses produced each year, the disposal of which awaits an economic solution.

Molasses in Europe has been put to a number of uses other than those enumerated above, but none are of any considerable importance, except that of the transformation of the sugars into alcohol, and the conservation of the residue from distillation for its fertilizing content. The alcohol is used mainly for industrial purposes, but until a few years ago, this application was heavily handicapped in the United States by the revenue requirements which limited its use on account of the high final cost to the consumer. By the passage of the denaturing act of June, 1906, Congress has made possible the use of alcohol in the arts and manufactures, and in the production of light and power. The production and employment of denatured spirit will gradually increase not only with the improved methods that will be evolved in its use, especially as regards light and power, but also with the higher cost of its chief competitors, the petroleum products, due to the ever increasing demand and diminishing amount of supplies. As the result of the new law, there were 3,364,590 gallons of denatured alcohol produced in the United States in 1907, and 3,874,625 gallons in 1908.<sup>3</sup> That derived from molasses furnishes a considerable proportion of the total. Herri<sup>4</sup> quotes from a report to the Fifty-ninth Congress, that ten of the beet sugar factories of Michigan sent their molasses to a distillery in that state in 1906, which produced about a million gallons of proof alcohol. It is with the object of learning to what extent, and with what profit to the islands, the waste molasses of our mills can contribute to the alcohol supply of the United States, that the work of this bulletin has been carried out.

## FERMENTATION.

Alcoholic fermentation implies finally the splitting up by yeasts of sugars into ethyl alcohol, carbonic acid, and, to a smaller extent, products such as succinic acid, glycerol, and some higher alcohols, the latter being usually grouped together as fusel oil. The amount of alcohol produced per unit of raw material depends on (1) the quantity of fermentable sugar present; (2) the nature of the yeast; (3) the conditions of the fermentation as regards cleanliness, sterility of containers, etc.; (4) the presence of sufficient nutrients for the optimum development of the yeast; (5) the proper control of the temperature; (6) and the efficiency of the distilling apparatus. The first condition can be controlled by analysis of the raw material and its dilution; the second by trials with various yeasts; the third by careful handling of yeasts, molasses and containers; the fourth can be supplied if necessary; the fifth can be controlled by proper cooling appliances; and the sixth depends on the selection of efficient apparatus and its correct handling.

The yeasts which are usually employed in distillery work belong to a class of micro-organisms known as saccharomycetes, of which there are many species, varieties, and races; the species most generally used is known as *Saccharomyces cerevisiae*. This is known as a budding yeast, on account of its method of reproduction, in contradistinction to fission-yeasts, which are classed as Schizosaccharomyces. These yeasts have the power of not only transforming into alcohol such sugars as dextrose and levulose, which exist in molasses and are usually reported as glucose, but also, by means of an enzyme which they secrete, called invertase, of changing sucrose into glucose, when it also can be fermented. Another enzyme secreted by the yeast, zymase, effects this transformation.

In past years, fermentation of molasses was initiated by adventitious yeasts, that is, the yeasts existing naturally on the cane or in the air. Subsequent fermentations were started from vats in fermentation, or by the yeast left in vats from previous fermentations. Where the object was as much to produce a certain aroma in the distilled product as well as the alcohol, the entrance of organisms other than yeasts was not a serious objection. Such ethereal flavors, however, are produced at the expense of the alcohol, and, besides, the entrance of organisms producing faulty fermentation and serious losses, cannot be prevented. Today, yeast production is carried on almost universally in accordance with the laws of "natural pure culture" formulated by Delbrück. The expert in fermentation is able to regulate the battle for supremacy between the fungi so that, it leads to the de-

struction of harmful organisms and to the survival of the desired culture yeast.<sup>5</sup>

The total sugars which can be fermented in a molasses are the sum of the sucrose and glucose. Theoretically sucrose should give 53.8 per cent. and glucose 51.11 per cent. of their respective weights as absolute alcohol. In practice the yield will be seen to be considerably less, even when working under the best conditions as regards yeast, sterility, and temperature control.

Before studying the comparative yields of alcohol from different molasses, it was necessary to obtain a supply of yeast, preferably of those who were acclimated to working in molasses under tropical conditions; absence of distilleries in the Hawaiian Islands prevented us obtaining a supply here. Accordingly, we wrote to correspondents in various parts of the world where distilleries are operated in conjunction with the cane sugar industry, and obtained from each of them a supply of the yeast used. The method adopted to forward the yeasts was as follows: From a vat of wash in active fermentation a few drops were allowed to fall on to a piece of filter paper; this, after rapidly drying in the air, was placed in an envelope and posted to us in Honolulu. In this way, we obtained yeast from Cuba, Demerara, Mauritius, Natal, Peru, and Trinidad. For these we are indebted to Mr. J. T. Crawley, to Mr. W. M. B. Shields, to Mr. L. Bulau, to Messrs. Harrison Brothers, to Mr. W. MacDougall, and to Mr. H. E. Murray; to these gentlemen we take this opportunity of expressing our thanks for their courtesies. The yeast that we have studied from Java was isolated from a sample of "Java yeast" or 'Raggi," forwarded through the courtesy of Mr. J. D. Kobus; yeast from this material has previously been isolated and studied by Went and Prinsen-Geerligs, who have named this species *Saccharomyces vordermannii*. In addition we obtained from the Institut für Gärungsgewerbe in Berlin cultures of the well known Race II and Race XII, distillery yeasts widely employed in European distilleries.

Upon receipt of each stock of yeast, the filter paper was dropped into a flask of sterile beer wort and placed in an incubator at 30° C. Fermentation started in from twenty-four to forty-eight hours, and from this fermentation a series of plate cultures in beer wort agar was made; a sufficient dilution was made so as to obtain plates with but one to six colonies in one plate; one of these colonies was picked out and inoculated into a sterile flask containing a stock molasses wort; the purity of the yeast under trial was proved by means of subcultures from time to time.

Preliminary trials showed that there was apparently, in the fermentation obtained from each source, but one dominant type of yeast. This is in accordance with the results obtained previ-

ously by one of us in a study of Demerara yeast. We did not then attempt to isolate a number of different races from the yeast obtained from any one source, but contented ourselves with studying in pure cultures one type derived from each source. This procedure was apparently justified as the alcohol producing powers of the yeasts derived from widely different localities were not very greatly divergent.

The molasses used for the comparative fermentations of the yeasts was obtained through the courtesy of Oahu Plantation, and was of the following composition:

		Inorganic Constituents.	
Total Solids.....	84.50	Ash .....	15.93
Brix .....	93.50	Iron and Aluminum Oxides. ....	.09
Sucrose, Polarization.....	32.5	Lime .....	1.90
Sucrose, Clerget.....	35.2	Magnesia .....	.98
Purity, True.....	41.7	Potash .....	4.89
Purity, Apparent.....	34.7	Phosphoric Anhydride.....	.14
Glucose .....	12.57	Sulphuric Anhydride.....	1.93
Total Sugars as Glucose....	49.53	Chlorine .....	3.02
Nitrogen .....	.64		

A stock wort was prepared by diluting this molasses to approximately the desired density, and placing it in a vessel of the Carlsberg type. It was sterilized by boiling for three successive days, air being allowed to enter after each sterilization through a sterile cotton plug. The wort was withdrawn through a glass tube previously sterilized. When not in use, the rubber exit tube was closed by a Mohr's clamp and glass stopper, which was flamed before each withdrawal. The flasks used for fermentation were eight ounce Erlenmeyers, plugged with cotton wool, and sterilized at a dry heat for one hour at 140° C.

The fermentations were conducted in an incubator of the type originally described by Koch,<sup>6</sup> at a temperature of 30° to 31° C.

For a pure culture apparatus, the apparatus as illustrated, Fig. 1, was found very convenient. Flask, A was filled with dilute molasses, and sterilized in an Arnold steam sterilizer for three successive days. The glass parts were all sterilized either by flaming or heating in an oven to 140° C., and the rubber parts by heating in an autoclave under 40 pounds pressure. The apparatus was connected rapidly, the hands of the operator being encased in surgeon's sterilized rubber gloves. The yeast chamber B is one of the parts of a Lunge nitrometer, graduated in parts of 10 cc. The operation of starting and using was as follows: A yeast being started in a Lister culture flask, this was connected with a piece of glass tubing to C. The culture flask was then raised, and the stop cock of B opened to D, when the culture solution passed into B. After sufficient of the liquid had entered, the pinch cock E was closed, the two pieces disconnected,

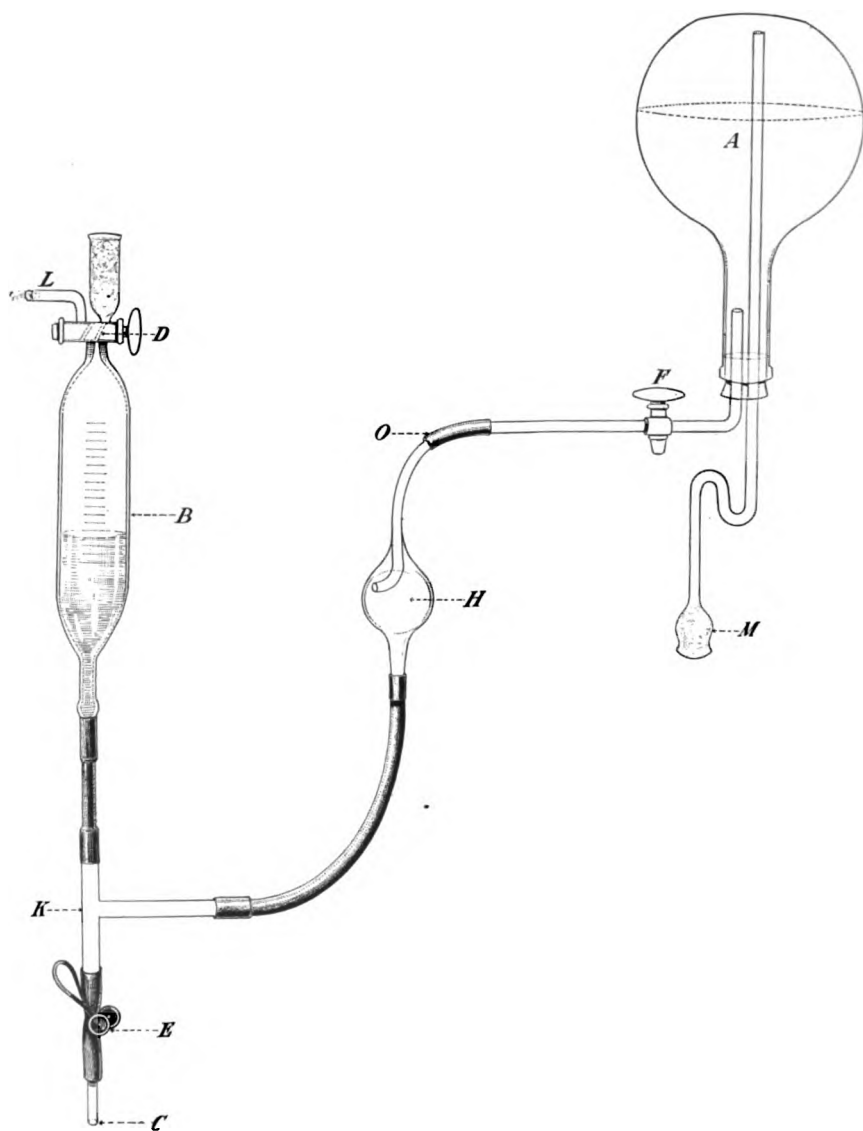


Fig. 1.

and a flamed piece of glass stirring rod used to close up C. The stop cock F being open, sterile molasses wort flowed into B through the trap H, air entering through the plug of sterile cotton at M, until it reached a sufficient height in B. After twenty-four hours the yeast was in active fermentation and ready for seeding into the flasks of the experiment. This was done by first closing stop cock at D, taking B from its support and shaking thoroughly. This was facilitated by having a sufficient length of rubber tubing between H and the "T" tube K. The stop cock of B was then opened to L to allow the escape of the carbonic acid gas without soiling the cotton at D. It was quickly turned as soon as this was effected and opened to D. The stirring rod was then replaced by glass tubing, and the mother yeast run into the flasks of the experiment, the amount being read off from the graduations on B. Afterwards the glass tubing was again replaced by a rod, the stop cock F opened, and fresh wort introduced to replace that withdrawn. In the event of the yeast mash not being used on any particular day, it was nevertheless partly run out and replaced by fresh wort, so that there was at all times a fresh and vigorous growth of yeast in B. After the completion of an experiment, all the parts were taken off from O, this closed with a rod, and the detached parts cleaned, sterilized, and again replaced, ready for a new yeast.

Fermentations were started by introducing a measured quantity of the mother yeast into a definite quantity of wort. The weight of the flasks and contents were noted at the time of starting and every twenty-four hours thereafter. The fermentation was concluded to be complete when no more loss of weight was apparent, and the total loss of weight was about equivalent to that of the carbonic acid which could be produced by the amount of sugars present in the wash. Blank experiments carried out with dilute alcohol showed that no appreciable loss of alcohol occurred during the time over which a fermentation lasted. The fermentations in the first series were carried on in the wort as derived from molasses and water, and also with the addition of sulphuric acid, sulphate of ammonia, and sodium phosphate, alone and in combination with each other. The reasons for these additions will appear later. The detailed results of the fermentations will be found in Table I.

TABLE I.  
FERMENTATIONS WITH DIFFERENT YEASTS.

Name of Yeast.	Time—Hours.....	Specific Gravity of Wort.....	Attenuation.....	Sugars per 100 cc..	Alcohol % Vol...	% Sugar Unfer- mented.....	† Alcohol % Total Sugars.....	Additions to Wort.
Cuba.....	120	1.0651	36.2	9.00	4.81	7.44	83.0	.....
"	120	1.0651	35.5	9.00	4.85	7.21	83.7	Am. Sul.
"	120	1.0651	35.1	9.00	4.76	6.66	82.2	Sul. Acid
"	120	1.0651	35.3	9.00	4.75	6.77	81.9	Sod. Phos.
"	119	1.0575	30.0	7.94	4.18	6.80	81.8	Am. Sul., Sul. Acid
"	119	1.0575	30.4	7.94	4.22	6.55	82.7	Am. Sul., Sod. Phos.
"	119	1.0575	29.7	7.94	4.25	7.05	83.2	Sul. Acid., Sod. Phos.
"	119	1.0575	29.7	7.94	4.25	7.18	83.2	3 Nutrients
Average.....	...	.....	...	...	...	5.96	82.7	.....
Demerara.....	117	1.0695	39.9	9.92	5.30	6.22	83.0	.....
"	117	1.0695	38.2	9.92	5.20	6.22	81.5	Am. Sul
"	117	1.0695	38.5	9.92	5.31	6.55	83.2	Sul. Acid
"	117	1.0695	37.8	9.92	5.27	6.22	82.6	Sod. Phos.
"	94	1.0695	38.0	9.92	5.50	6.55	86.2	Am. Sul., Sul. Acid
"	94	1.0695	37.5	9.92	5.32	6.44	83.4	Am. Sul., Sod. Phos.
"	94	1.0695	37.6	9.92	5.55	6.65	86.8	Am. Sul., Sod. Phos.
"	94	1.0695	36.7	9.92	5.38	6.55	84.2	3 Nutrients
Average.....	...	.....	...	...	...	6.43	83.9	.....

† See foot note on page 17.

TABLE I—Continued.  
FERMENTATIONS WITH DIFFERENT YEASTS.

Name of Yeas.	Time—Hours.....	Specific Gravity of Wort.....	Attenuation.....	Sugars per 100 cc..	Alcohol % Vol...	% Sugar Unfer- mented.....	† Alcohol % Total Sugars.....	Additions to Wort.
Java.....	196	1.0776	42.4	10.51	5.48	6.29	81.0	.....
".....	196	1.0737	39.8	9.98	5.17	6.31	80.6	Am. Sul.
".....	196	1.0737	40.2	9.98	5.45	6.51	85.0	Sul. Acid
".....	196	1.0737	39.7	9.98	5.17	6.51	80.6	Sod. Phos.
".....	96	1.0702	38.5	9.51	4.93	6.52	80.4	Am. Sul., Sul. Acid
".....	72	1.0702	36.3	9.51	4.90	6.50	80.0	Am. Sul., Sod. Phos.
".....	120	1.0702	37.3	9.51	5.15	6.20	84.2	Sul. Acid, Sod. Phos.
".....	96	1.0670	35.1	9.07	4.80	6.50	82.3	3 Nutrients
Average.....	...	....	...	..	...	6.42	81.8	.....
Mauritius.....	138	1.0651	34.9	9.00	4.80	7.66	82.8	.....
".....	138	1.0651	34.9	9.00	4.75	6.32	81.9	Am. Sul.
".....	138	1.0651	34.0	9.00	4.80	7.88	82.8	Sul. Acid
".....	138	1.0651	34.4	9.00	4.75	7.55	81.9	Sod. Phos.
".....	138	1.0575	29.3	7.94	4.24	7.05	83.0	Am. Sul., Sul. Acid
".....	138	1.0575	29.9	7.94	4.25	6.68	83.2	Am. Sul., Sod. Phos.
".....	138	1.0575	29.2	7.94	4.24	7.56	83.0	Sul. Acid, Sod. Phos.
".....	138	1.0575	28.6	7.94	4.26	6.68	83.5	3 Nutrients
Average.....	...	....	...	..	...	7.17	82.8	.....

† See foot note on page 17.



TABLE I—Continued.  
FERMENTATIONS WITH DIFFERENT YEASTS.

Name of Yeast.	Time—Hours....	Specific Gravity of Wort.....	Attenuation.....	Sugars per 100 cc..	Alcohol % Vol...	% Sugar Unfermented.....	† Alcohol % Total Sugars.....	Additions to Wort.
Natal 1.....	120	1.0776	42.0	10.51	5.46	6.57	80.8	.....
".....	72	1.0700	38.0	9.98	5.27	6.61	82.2	Am. Sul.
".....	96	1.0700	37.7	9.98	5.33	8.71*	82.9	Sul. Acid
".....	120	1.0700	38.5	9.98	5.25	6.31	81.8	Sod. Phos.
".....	96	1.0695	37.9	9.92	5.32	6.45	83.4	Am. Sul., Sul. Acid
".....	96	1.0695	37.6	9.92	5.14	6.65	80.5	Am. Sul., Sod. Phos.
".....	120	1.0695	37.4	9.92	5.28	6.45	82.6	Sul. Acid, Sod. Phos.
".....	96	1.0695	36.9	9.92	5.26	6.85	82.4	3 Nutrients
Average.....	...	....	...	...	...	6.56	82.1	.....
Natal 2.....	120	1.0695	38.6	9.92	5.30	6.44	83.0	.....
".....	96	1.0695	38.6	9.92	5.42	6.65	85.0	Am. Sul.
".....	96	1.0695	37.8	9.92	5.52	7.06	86.6	Sul. Acid
".....	96	1.0695	37.4	9.92	5.42	6.55	85.0	Sod. Phos.
".....	96	1.0695	38.5	9.92	5.50	6.44	86.2	Am. Sul., Sul. Acid
".....	96	1.0695	38.5	9.92	5.23	6.90	81.8	Am. Sul., Sod. Phos.
".....	96	1.0695	38.0	9.92	5.38	6.44	84.2	Sul. Acid, Sod. Phos.
".....	96	1.0695	39.0	9.92	5.38	6.60	84.2	3 Nutrients
Average.....	...	....	...	...	...	6.63	84.5	.....

\* Not included in average.

† See foot note on page 17.

TABLE I—Continued.  
FERMENTATIONS WITH DIFFERENT YEASTS.

Name of Yeast.	Time—Hours.....	Specific Gravity of Wort.....	Attenuation.....	Sugars per 100 cc..	Alcohol % Vol...	% Sugar Unfermented.....	† Alcohol % Total Sugars.....	Additions to Wort.
Peru.....	168	1.0776	42.8	10.51	5.64	6.26	83.2	.....
“.....	144	1.0737	40.0	9.98	5.45	6.48	85.0	Am. Sul.
“.....	144	1.0737	41.2	9.98	5.27	6.78	82.1	Sul. Acid
“.....	144	1.0737	40.0	9.98	5.18	6.70	80.6	Sod. Phos.
“.....	144	1.0702	38.2	9.51	5.09	6.40	83.1	Am. Sul., Sul. Acid
“.....	144	1.0702	37.3	9.51	5.00	6.52	81.7	Am. Sul., Sod. Phos.
“.....	168	1.0702	37.6	9.51	4.98	6.52	81.3	Sul. Acid, Sod. Phos.
“.....	144	1.0670	35.0	9.07	4.65	6.85	80.0	3 Nutrients
Average.....	...	....	...	...	...	6.56	82.1	.....
Trinidad.....	96	1.0610	32.5	8.44	4.30	7.00	79.4	.....
“.....	72	1.0610	32.5	8.44	4.36	6.28	82.4	Am. Sul.
“.....	72	1.0610	32.1	8.44	4.33	6.40	79.8	Sul. Acid
“.....	72	1.0610	32.5	8.44	4.29	6.40	79.1	Sod. Phos.
“.....	72	1.0610	32.9	8.44	4.40	6.75	81.2	Am. Sul., Sul. Acid
“.....	72	1.0610	31.1	8.44	4.35	6.28	80.3	Am. Sul., Sod. Phos.
“.....	72	1.0610	31.7	8.44	4.45	6.75	82.1	Sul. Acid, Sod. Phos.
“.....	72	1.0610	31.5	8.44	4.35	7.46	80.3	3 Nutrients
Average.....	...	....	...	...	...	6.67	80.6	.....

† See foot note on page 17.

TABLE I—Continued.  
FERMENTATIONS WITH DIFFERENT YEASTS.

Name of Yeast.	Time—Hours ....	Specific Gravity of Wort.....	Attenuation.....	Sugars per 100 cc.	Alcohol % Vol....	% Sugar Unfermented .....	† Alcohol % Total Sugars .....	Additions to Wort.
Race II.....	94	1.0695	38.3	9.92	5.45	7.26	85.4	.....
".....	94	1.0695	36.6	9.92	5.52	7.56	86.6	Am. Sul.
".....	94	1.0695	36.7	9.92	5.55	7.56	86.8	Sul. Acid
".....	94	1.0695	36.6	9.92	5.60	6.95	87.6	Sod. Phos.
".....	92	1.0695	37.7	9.92	5.34	6.22	83.6	Am. Sul., Sul. Acid
".....	92	1.0695	37.5	9.92	5.31	7.36	83.2	Am. Sul., Sod. Phos.
".....	92	1.0695	37.6	9.92	5.33	5.95	83.4	Am. Sul., Sod. Phos.
".....	92	1.0695	38.0	9.92	5.26	6.22	82.4	3 Nutrients
Average.....	...	...	...	...	...	6.89	84.9	.....
Race XII.....	116	1.0695	38.5	9.92	5.35	6.25	83.8	.....
".....	116	1.0695	38.5	9.92	5.20	5.85	81.5	Am. Sul.
".....	116	1.0695	37.9	9.92	5.25	7.20	82.2	Sul. Acid
".....	116	1.0695	37.6	9.92	5.11	6.76	80.1	Sod. Phos.
".....	91	1.0695	37.4	9.92	5.27	6.25	82.6	Am. Sul., Sul. Acid
".....	91	1.0695	37.2	9.92	5.27	5.95	82.6	Am. Sul., Sod. Phos.
".....	91	1.0695	36.0	9.92	5.19	7.90	81.3	Sul. Acid., Sod. Phos.
".....	91	1.0695	37.0	9.92	5.20	6.05	81.5	3 Nutrients
Average.....	...	...	...	...	...	6.54	82.0	.....

† See foot note on page 17.

The average yields are from a minimum of 80.6 per cent. of the theoretical, with the Trinidad yeast, to 84.9 per cent. with Race II.\* These differences are not very great when it is considered that a variation of one-tenth per cent. by volume of alcohol in a wort containing 8.44 per cent. of sugars indicates a difference of 1.8 per cent. in the yield.

The washes for these determinations were set up at specific gravities varying from 1.0575 to 1.0776 with sugar contents of from 7.94 to 10.51 grams per 100 cc. The usual density of setting up washes in rum distilleries is 1.060, but molasses in countries making rum contain more sugars than do those of Hawaii. Most yeasts are weakened in their action when the fermenting liquid begins to exceed six or seven per cent. of alcohol, leaving sugar unfermented. The worts, therefore, must be made of such strength in sugars, that the final wash will not contain an excessive amount of alcohol. However, in late years yeasts have been cultivated that will withstand a much higher alcohol content than has usually been considered safe. Thus, according to Went and Geerligs,<sup>7</sup> *Saccharomyces vordermannii* can convert the glucose in a solution of 18 to 19 per cent. entirely into alcohol and the by-products. The advantages of such a procedure are many. Yeast remains purer in concentrated mashes because the fermentation of the greater quantities of sugar which these mashes contain, yields more alcohol than in thinner mashes, and alcohol acts as a powerful poison towards schizomycetes and to dangerous varieties of yeast which are liable to work considerable damage.<sup>5</sup> According to Maercker,<sup>5</sup> a concentrated mash can be operated which will yield as high as 12 per cent. of alcohol. Another series of fermentations was accordingly carried out, to see if stronger concentrations would produce as good results, the results of which are given in Table II.

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\* The theoretical yield of alcohol is .5111 times the weight of glucose. Thus a wort containing 9.92 grams of sugar in 100 cc. should give a distillate of equal volume containing 5.07 grams of alcohol per 100 cc. If this distillate contains but 4.25 grams in 100 cc. (which is equivalent to 5.35 per cent. by volume), the alcohol obtained, expressed in terms of sugars, is 83.8 per cent. The maximum yield, according to Pasteur, is really 94.83 per cent. of the theoretical, the remainder forming the usual by-products of fermentation, principally glycerol and succinic acid. The extreme yield of the above yeasts would, according to this standard, be 84.99 to 89.4 per cent. In reporting results in this bulletin, the percentage on the theoretical, calculated from the formula, and not the maximum yield to be obtained in practice, will always be indicated.

TABLE II.  
 FERMENTATION OF WORTS OF HIGH DENSITIES WITH DIFFERENT YEASTS.

Name of Yeast.	Time Hours.	Spec. Grav. of Wort.	Attenuation.	Sugars per 100 cc.	Alcohol % Vol.	% Sugars Unfermented.	Alcohol * % Total Sugars.
Cuba.....	67	1.0826	47.0	11.26	6.18	6.84	85.4
".....	91	1.0912	51.0	12.43	6.80	6.68	85.0
".....	91	1.1001	58.0	13.64	7.30	6.59	83.2
Demerara.....	95	1.0805	44.9	11.42	5.98	6.13	81.3
".....	94	1.0899	50.4	12.84	6.76	6.08	81.9
".....	115	1.1023	56.5	14.60	7.68	6.10	81.6
Java.....	95	1.0805	45.0	11.42	6.20	5.95	84.4
".....	116	1.0899	50.2	12.84	6.68	6.00	80.8
".....	115	1.1023	56.9	14.60	7.68	6.23	81.6
Mauritius.....	72	1.0826	44.0	11.26	6.15	6.84	84.8
".....	96	1.0912	49.8	12.43	6.75	7.08	84.4
".....	144	1.1001	55.5	13.64	7.15	6.74	81.5
Natal 1.....	95	1.0805	45.0	11.42	6.05	6.57	82.2
".....	92	1.0899	49.9	12.84	6.85	6.08	82.9
".....	163	1.1023	56.1	14.60	7.25	6.10	77.2
Natal 2.....	95	1.0805	45.0	11.42	5.98	5.78	81.3
".....	94	1.0899	49.9	12.84	6.85	5.92	82.9
".....	115	1.1023	57.2	14.60	7.60	6.10	81.0
Peru.....	95	1.0805	46.1	11.42	6.25	5.86	84.9
".....	92	1.0899	51.1	12.84	7.00	6.00	84.8
".....	115	1.1023	58.1	14.60	7.85	6.00	83.5
Trinidad.....	95	1.0805	45.1	11.42	6.00	5.78	81.5
".....	94	1.0899	49.9	12.84	6.87	6.00	83.2
".....	163	1.1023	56.7	14.60	7.55	5.90	80.4
Race II.....	116	1.0805	45.8	11.42	6.31	5.69	85.8
".....	139	1.0899	49.8	12.84	6.80	5.76	82.3
".....	139	1.1023	56.8	14.60	7.71	5.77	82.0
Race XII.....	89	1.0805	45.2	11.42	5.85	5.86	79.5
".....	89	1.0899	49.6	12.84	6.60	6.23	79.9
".....	89	1.1023	55.8	14.60	7.45	5.96	79.3

\* See foot note on pag. 17.

A word of explanation must first be offered in regard to an apparent inconsistency between the results of this table and those of Table I. In the second table, seven yeasts show a larger percentage yield in the first concentration over the averages obtained in the lower concentrations of Table I; and in most cases, notably that of the yeast from Peru, the time of fermentation is materially lessened. In seeding the worts described in Table I, 10 cc. of mother yeast from the previously described apparatus was used. After fermentation, a heavy sediment of yeast is formed, and on these sediments the worts of Table II were started. With the smaller number of yeast cells in the first instance, the time of fermentation was longer; and other things being equal, the longer the fermentation the greater is the liability to the formation of by-products, such as volatile acids, at the expense of the alcohol. This obtains also in operations on a commercial scale, where to the possibility of loss in this direction must be added that arising from evaporation and the danger of infection.

The results show that in the work of the first series, the limit of sugar content was not overstepped. A selection of yeasts was then possible for comparative work on molasses from different mills. Our choice fell on Race II and the yeast from Peru, the former because in this first series, it produced the highest average yields, and the latter because of its being of a different genus, viz., fission yeast, and, furthermore, showed commendable qualities in the stronger worts. Fermentations were carried on both by seeding from a mother yeast, and on the sediment from this fermentation. In all but two instances, the results from Race II were superior to those with the yeast from Peru, and only the results from the second series of fermentations with this yeast are accordingly reported. Table III contains the analyses of the molasses used, and Table IV the results of the fermentations.

TABLE III.

## COMPOSITION OF MOLASSES.

Total Sugars %..	54.25 46.40 46.29 50.95 60.35 50.40 59.18 47.48 55.10 49.20 49.08 52.68 52.98 50.10 48.20 46.49 57.17 49.53 47.63 49.26 55.63 55.63 53.55 49.80 54.65
Chlorine.....	2.46 1.78 1.77 2.09 1.93 2.74 2.04 2.07 2.73 2.55 2.61 1.34 2.63 1.92 3.04 1.28 1.56 3.02 1.54 2.05 8.43 .85 2.09 1.28 2.51
Nitrogen.....	.28 .87 1.64 .33 .33 .48 .24 .75 .42 .51 .58 1.05 .60 .59 .97 .77 .33 .64 .91 1.06 .84 .62 .61 .35 .44
Ash.....	10.43 10.04 7.22 10.90 10.06 12.47 10.26 12.31 9.45 10.85 11.80 8.65 14.55 11.57 12.84 10.17 35.7 15.93 9.28 10.55 13.61 6.74 9.54 7.92 11.65
Glucose Ratio...	66.3 31.3 20.9 33.1 84.1 20.4 72.9 32.8 52.6 37.3 24.0 36.8 22.4 30.4 14.6 68.2 35.7 44.5 21.3 15.9 78.0 53.1 44.3 42.0
Glucose.....	21.02 10.70 7.70 12.20 26.85 8.19 24.27 11.30 18.40 12.92 9.13 13.67 9.30 11.25 5.90 22.52 12.57 14.19 8.66 7.19 23.71 18.01 14.78 15.64
Sucrose, Clerget...	31.7 34.1 36.8 36.9 31.9 40.2 33.3 34.5 35.0 34.6 38.1 37.2 41.5 37.0 40.3 33.0 35.2 31.9 40.6 45.3 30.4 33.9 33.4 37.2
Sucrose, Direct...	27.5 27.0 30.5 35.5 27.5 38.0 28.0 27.5 28.8 31.0 32.5 28.0 36.0 33.5 38.0 31.5 32.5 23.0 35.5 40.0 23.5 30.5 34.0 32.0
Purity, Apparent.	32.0 31.2 39.3 43.6 30.6 42.2 30.0 32.4 32.7 36.6 34.6 33.7 39.1 41.0 41.7 36.4 34.7 27.9 41.2 43.7 27.7 34.7 36.2
Purity, True.....	38.7 40.8 ... 46.3 37.5 48.8 39.9 42.4 42.4 43.3 44.3 45.2 49.4 45.1 47.9 41.5 41.4 41.7 39.1 48.7 51.6 36.8 40.7 45.3
Brix.....	86.0 86.7 77.5 81.4 89.9 90.0 86.5 92.0 87.9 84.6 93.9 83.0 92.0 81.7 91.2 86.9 86.4 93.5 82.5 86.2 91.5 84.9 87.9 79.3 88.4
Total Solids.....	81.8 83.8 ... 79.6 85.0 82.4 83.3 86.9 82.5 79.9 86.0 82.3 84.0 82.1 84.1 83.2 79.7 84.5 81.5 83.3 87.8 82.7 83.4 ... 82.1
Number *.....	5 7 22 16 6 26 13 37 25 40 38 41 27 21 39 36 18 20 34 24 48 3 17 2 1

\* These numbers are the same as those used to identify mills in the Annual Synopsis of Mill Data.

TABLE IV.  
FERMENTATION OF MOLASSES FROM DIFFERENT MILLS.

Number.....	Time, Hours.....	Specific Grav of Wort.....	Attenuation.....	Sugars in Wort grams per 100 cc.....	% Sugars Unfermented...	Alcohol * % Total Sugars.....	Alcohol % Fer- mented Sugars..	Gallons of U. S. Proof Alcohol per Gallon Molasses.....
5	95	1.0713	46.4	11.62	6.80	82.8	89.0	.80
7	72	1.0723	39.6	9.95	7.04	79.1	85.0	.66
22	96	1.0651	40.0	9.86	6.89	77.8	83.4	.62
16	96	1.0679	45.1	10.88	5.88	85.6	91.0	.80
6	72	1.0746	52.4	12.97	7.32	81.4	87.9	.89
26	95	1.0749	44.5	10.84	4.15	83.0	86.8	.76
13	120	1.0730	51.5	12.70	6.69	90.0	96.3	.93
37	94	1.0752	41.3	10.21	8.62	81.4	89.1	.73
25	96	1.0728	49.0	11.82	6.01	85.9	91.3	.87
40	71	1.0708	42.9	10.53	4.65	84.7	88.9	.74
38	96	1.0779	42.8	10.58	6.14	82.4	88.0	.75
41	96	1.0697	47.1	11.27	7.01	81.2	87.3	.75
94	94	1.0760	46.5	11.40	5.26	84.0	88.6	.83
27	94	1.0693	44.3	10.71	4.58	83.7	87.7	.74
21	94	1.0762	42.6	10.37	4.05	80.8	84.2	.71
39	72	1.0701	41.2	9.95	6.53	81.7	87.2	.71
36	72	1.0723	49.4	12.26	7.91	84.3	91.5	.86
18	144	1.0772	42.3	10.67	6.19	83.3	88.7	.76
20	120	1.0772	42.3	10.67	7.07	78.3	85.0	.65
34	96	1.0686	41.2	10.18	5.11	83.3	87.9	.78
24	96	1.0720	44.1	10.56	5.48	83.6	88.5	.86
48	96	1.0765	48.5	12.22	7.47	83.7	90.6	.83
3	95	1.0706	48.7	11.91	5.74	81.6	86.6	.79
17	94	1.0740	46.7	11.50	5.61	89.0	94.4	.73
2	119	1.0380	42.1	10.33	5.12	85.5	90.1	.81
1	96	1.0724	47.6	11.72				

\* See foot note on page 17.



In Table III is again to be noticed the immense variation in molasses from different mills as was previously reported in a bulletin of this Station.<sup>8</sup> In appraising molasses for its value as an alcohol maker, not only the sucrose but also the glucose must be taken into account, since it also is converted into alcohol. Naturally, therefore, the usual standard of judging a molasses, viz., its purity, gives no clue as to what it may be worth for fermentation purposes. Thus molasses 6 and 13 with low purities of 37.5 and 39.9 respectively contain 60.35 and 59.18 per cent. of total sugars, whilst 39 and 24 with purities of 47.9 and 48.7 respectively contain only 48.2 and 48.26 per cent. of total sugars.

The yield of alcohol per gallon molasses corresponds, of course, closely to the percentage of total sugars, varying from .62 to .93 gallons of U. S. proof spirit, the average of all being .77 gallons. This is a most important point to consider, if ever the disposal of molasses in this manner is contemplated. The United States revenue regulations regarding molasses distilleries contain this clause<sup>9</sup>: "The quantity of spirit which can be produced from a gallon of molasses varies, of course, with the completeness of the apparatus and quality of the material, from 80 to 95 per cent.,—from 85 to 90 per cent. probably being a fair average; and in no case should a less allowance than this average be made without first submitting a full report of the reasons thereof to the Commissioner." That is, unless this regulation be modified for the special circumstances of Hawaiian molasses, the revenue authorities could insist on the payment of revenue on 85 gallons of proof spirit per 100 gallons of molasses fermented, whether they are obtained or not.

The evidence of this series of fermentations, therefore, is that on an average there can be obtained from one gallon of waste molasses .77 gallon of proof spirit or .385 gallon of absolute alcohol. But this represents only 83 per cent. of the theoretical amount possible. From 5 to 6 per cent. is used in the formation of by-products, as determined by Pasteur. Of that remaining, an average of 6.13 per cent. can be accounted for by that amount of reducing bodies remaining unfermented in the wash. This varies in individual molasses from 4.05 to 8.62 per cent., and was the same with both Race II and Peru yeast. That this is not a result of yeast variation, strength of wort, amount of yeast present, or lack of nutrients, is sufficiently attested by the results of Tables I and II. The averages of these two show 6.68 and 6.15 per cent. of sugars unfermented, while this same molasses gives 6.19 per cent. in Table IV, or an average of all of 6.41 per cent., amounting to 3.17 per cent. on the weight of the molasses. The average of all molasses in Table IV would indicate that 3.17 per cent. of the molasses was an unfermentable body, which reduces copper as does glucose, and is included with it in the determination of the sugars.

## THE UNFERMENTABLE SUGAR OF HAWAIIAN MOLASSES.

The presence of such bodies is not peculiar to the molasses of these islands, but their identity has not been established. In Queensland, Harker<sup>10</sup> found that there were reducing bodies left in the wash amounting to 2.46 per cent. of the molasses, or 4.65 per cent. of the sugars, while the percentage yield of alcohol calculated on the total sugars present amounted to about 82 per cent. In Egyptian cane-molasses, Pellet and Meunier<sup>11</sup> report 2.4 per cent. of glucose, a non-fermentable reducing body. Glucose is a hexose sugar of the same composition as dextrose, and is described by Maquenne<sup>12</sup> as "one of the products of isomerism, (or a mixture of other products yet unknown), which takes place when glucose, mannose, or levulose is submitted to the action of alkalis. It is an uncrystallizable, inactive, and unfermentable substance, with a reducing power considerably less than that of glucose. It appears to exist in tropical molasses, which is explained by the isomerizing action of the lime employed in treatment on the reducing sugars which accompany the sucrose in the juice." Hazewinkel,<sup>13</sup> who has just completed a thorough investigation on the composition of Java molasses, reports that at least in molasses from defecation in that country, there is a total absence of detectable glucose or mannose. Shorey<sup>14</sup> found xanthine bases and identified guanine in both juice and molasses of Hawaii. He cautions against the use of the gravimetric method in determining reducing sugars, as the guanine precipitate would cause the results to appear too high, unless the copper is determined electrolytically. In this bulletin, the sugars were determined by the Munson and Walker method, and the copper determined by the volumetric method of de Haen as modified by Low, so no error could be ascribed to this source in this work. Browne<sup>15</sup> found in Louisiana molasses that 23.83 per cent. of the total nitrogen existed in nitrogen assisted in nitrogen bases, as xanthine.

Finally, one of us<sup>16</sup> found in wash from the fermentation of Demerara molasses three per cent. on the weight of the molasses of reducing bodies, so that the presence of this unfermentable substance may be regarded as universal.

Besides those substances, there are others existing in molasses which are probably equally responsible for the presence of a reducing body which is not fermentable. The final molasses always contains some quantities of caramel, which reduces Fehling solution; the nitrogen is present chiefly as aspartic acid, which also effects a precipitation in the copper reagent; and finally, we were able to identify the presence of a pentose sugar by boiling the lees with dilute acid, when the distillate gave a distinct furfural test with anilin acetate. Furthermore, the lees was clarified with

subacetate of lead, filtered, the lead removed, and the evaporated filtrate taken up with alcohol, filtered and evaporated. The residue was purified by repeated solutions in alcohol. Finally a product was obtained which was dextrorotary and reduced Fehling solution. Its general appearance would indicate a pentose sugar, but it could not be obtained in sufficient quantities to make a positive identification.

While of sufficient interest to warrant further investigation, the identification of this substance or substances is not so important for the purpose of this bulletin as the realization of its presence, and in making an estimate of the value of molasses for fermentation allowance must be made on this account. The presence of these bodies does not, however, account for all the disparity between the theoretical yield of alcohol and that actually obtained. Of the causes which might contribute to this, the following suggest themselves as the most probable:

1. Inability of the yeast to convert all of the sugars into alcohol.
2. Presence in the molasses of non-sugars inimical to complete fermentation.
3. Lack of one or more essential nutrients.
4. Bacterial infection.
5. Inactivity of the yeasts due to insufficient aeration.
6. Necessity for stimulants.

These points were examined as indicated below.

1. Deportment of Race II in pure sugar solution.

For the purpose of this determination, the following nutrient solution was used:

Sugar (white granulated).....	100.0	grams per liter
Peptone .....	1.0	" " "
Sulphate of Ammonia.....	2.0	" " "
Sodium and Potassium Tartrate.....	2.0	" " "
Potassium Phosphate .....	2.0	" " "
Calcium Chloride .....	0.2	" " "
Magnesium Sulphate .....	0.4	" " "
Manganese Sulphate .....		trace

The data of the fermentation are given in Table V.

TABLE V.  
FERMENTATION OF PURE SUGAR SOLUTION.

Specific Grav. of Wort.	Attenuation.	Sugars per 100 cc., as Invert Sugar.	Alcohol % Vol.	Alcohol % of Total Sugars.
1.0494	45.8	10.53	6.43	94.8
1.0494	45.5	10.53	6.48	95.5
1.0494	45.4	10.53	6.40	94.4
1.0494	45.4	10.53	6.49	95.7

The average per cent. alcohol produced was 95.1 per cent., approximately Pasteur's maximum possible yield. It is at once evident that Race II was able to invert and completely transform all the sucrose in a solution containing 10.53 per cent. of sugars, into alcohol and the usual by-products. In no case was there more than a trace of reducing bodies present after the completion of the fermentation.

2. Influence of non-sugars in the molasses on the fermentation.

(a) First the effect of removing the impurities precipitable by subacetate of lead was studied. The invert sugar carried down with the lead precipitate was disregarded; the filtrate was freed of lead by sulphuretted hydrogen, boiled to remove the excess of gas, neutralized with carbonate of lime, and slightly acidulated with sulphuric acid. The clear filtrate was sterilized and fermented with Race II, with results as follows:

Time, Hours....	Spec Grav. of Wort.....	Attenuation....	Sugars per 100 cc....	Alcohol % Vol..	Alcohol % Total Sugars.....	% Sugar Unfer- mented.....
120	1.0628	27.3	7.60	4.15	85.1	7.36
96	1.0628	29.7	7.60	4.03	82.5	5.92
Average	.....	...	...	...	83.8	6.64

It is apparent that the non-sugars removed by subacetate of lead have no adverse effect on the fermentation, and that the reducing sugar which is not fermentable is not precipitated by the basic lead solution.

(b) Secondly, a solution of cane sugar was made in the spent wash or lees, and fermented. For this purpose, after determining the amount of reducing bodies in a lees, granulated sugar was dissolved therein, and the volume brought to what it was before the addition of the sugar. Total sugars were then determined as reducing sugars. The original lees contained .65 grams reducing sugars per 100 cc.; after addition of the sugar and concentration to the same volume as before the addition, the wort contained 10.3 grams sugars per 100 cc. Fermentation was started on sedimentary yeasts, and was very quick in starting up and finishing in every instance. The results are given in Table VI.

TABLE VI.  
FERMENTATION OF SUGAR DISSOLVED IN LEES.

Yeast.....	Time, Hours.....	Spec. Grav. of Wort.....	Attenuation.....	Total Sugars in 100 cc.....	Alcohol % Vol....	Alcohol % Total Sugars.....	Unfermented Sugars in Wash per 100 cc.....	Alcohol % Sugar Fermented.....
Race II..	65	1.0756	42.4	10.30	5.85	88.2	.63	93.9
Demerara..	65	1.0756	41.4	10.30	5.85	88.2	.61	93.7
Natal 2...	65	1.0756	42.1	10.30	5.78	87.1	.69	93.3
Trinidad..	65	1.0756	41.9	10.30	5.80	87.4	.69	93.7

Practically all the sugar added is found in the resulting wash as alcohol, so that it is obvious that nothing in the non-sugars of the molasses, either mineral or organic, has a deterring effect on the efficient working of the fermentation.

Another series was carried out with a new mixture with identical results. In addition, this same lees, diluted with an equal amount of water and with the same amount of added sugar, was fermented. Probably owing to the smaller quantity of nutrients present, the fermentation was much slower and not so satisfactory. On the other hand, it will appear from experiments carried out in connection with another point, that decided increase of the non-sugars in a wort, by diluting molasses with lees instead of water, also produces inferior results. The results of the second series of sugar and lees fermentations are presented in Table VII.

TABLE VII.  
FURTHER FERMENTATION OF SUGAR DISSOLVED IN LEES.

Yeast.....	Time, Hours.....	Spec. Grav. of Wort.....	Attenuation.....	Total Sugars in 100 cc. Grams...	Alcohol % Vol....	Alcohol % Total Sugars.....	Unfermented Sugars in Wash per 100 cc. Grams.....	Alcohol % Fer- mented Sugars..
Trinidad..	168	1.0885	47.7	11.46	6.43	87.0	.91	94.6
".....	288	1.0658	45.1	10.90	6.10	86.9	.45	90.6
Peru.....	96	1.0885	48.6	11.46	6.53	88.4	.79	95.0
".....	168	1.0658	41.1	10.90	5.90	84.0	.49	88.0
Java.....	120	1.0885	44.9	11.46	6.23	84.3	1.11	93.4
".....	168	1.0658	42.3	10.90	5.95	84.5	.85	91.8

### 3. Effect of Added Nutrients.

(1) *Nitrogen*. Nitrogen is added as food for the yeasts, generally in the form of sulphate of ammonia. The usual quantity is ten pounds to each thousand gallons of wash.<sup>17</sup> The result of this addition is to produce a quicker fermentation by inducing a more vigorous growth of the yeast; and while the final outcome of alcohol under sterile conditions might be no greater, by lessening the time of fermentation in commercial work with exposed fermenting tanks, the danger of infection from without by the entrance of unwholesome organisms is avoided. Other nitrogenous foods, such as yeast extracts and peptones, have been suggested, but seem to have found no extensive application. However, there is usually a sufficiency of nitrogenous matter in molasses, mostly in the form of amido bodies, as asparagine or aspartic acid, both of which are favorable forms of this element. According to Pringsheim,<sup>18</sup> with a too high concentration of nitrogenous matter fermentation is retarded, and he states that the best concentration of nitrogen is .004 to .008 per cent. Below this, fermentation is again retarded owing to starvation of the yeast. The molasses used in this work contained from 0.24 to 1.06 per cent. of nitrogen, whence the worts would contain from .05 to .2 per cent., thus containing more than a sufficiency of this element. The effect of added nitrogen in the form of sulphate of ammonia is shown in the fermentations given in Table I, from which the averages are taken to form Table VIII. The wort itself contained 0.8 gram nitrogen per liter.\*

TABLE VIII.

## EFFECT OF AMMONIUM SULPHATE.

Character of Wort.	% Total Sugars as Alcohol.	Increase or De- crease Due to Ammonium Sulphate.
.....	82.54	.....
Ammonium Sulphate.....	83.04	+ 0.50
Sulphuric Acid.....	83.36	.....
Sulphuric Acid and Amm. Sulphate	83.15	— 0.21
Sodium Phosphate.....	82.12	.....
Sodium Phosphate and Amm. Sulph.	81.94	— 0.18

The differences due to the ammonia are not significant. As regards the rate of fermentation, no material benefit appeared to result either as to the initial velocity or time of completion. It

\* Ammonium sulphate was added at the rate of 1.2 grams, sulphuric acid 1 cc., and sodium phosphate 2 grams per liter.

must not be concluded from this that the same negative result would be obtained when working with large masses. On the contrary, the experience of fermentation industries throughout the world point to very decided advantages from the use of this substance. Whether or no the molasses from Hawaii will prove an exception cannot be decided except by trials on a large scale.

(2) *Phosphates.* Delbrück<sup>19</sup> found that salts of phosphoric acid stimulate the fermentative power of yeasts in a most marked degree; and Young<sup>20</sup> states that soluble phosphates increase the rate of evolution of carbonic oxide. Lange<sup>21</sup> mentions as economical yeast foods potassium and ammonium phosphates, while Barbet<sup>22</sup> found that supplying the yeast with such foods as peptone and phosphoric acid considerably increased its ability to multiply and secrete sufficient sucrase to invert the sugar. Hawaiian molasses are greatly deficient in phosphates when compared with other sources of alcohol, such as potatoes and grains, which already contain a sufficiency of this substance.<sup>5</sup> That used in this work contained .14 per cent. of phosphoric anhydride, whence the wort would have less than .03 per cent. The following averages taken from Table I show the effect of added phosphate:\*

TABLE IX.  
EFFECT OF PHOSPHORIC ACID.

Character of Wort.	% Total Sugars as Alcohol.	Increase or De- crease Due to Phosphate. Sodium
.....	82.54	.....
Sodium Phosphate.....	82.12	— 0.42
Ammonium Sulphate.....	83.04	.....
Am Sulphate and Sod. Phosphate..	81.94	— 1.10
Sulphuric Acid.....	83.36	.....
Sul. Acid and Sod. Phosphate.....	83.21	— 0.15

The effect of this addition was, apparently, to diminish the yield of alcohol, and as with ammonium sulphate, the rate of fermentation was in nowise affected. The objection might be presented that it would have been better to have used the salt of potash instead of that of soda, potash phosphate being usually supplied in artificial nutrient mixtures. The molasses, however, already contains a heavy percentage of potash, large quantities of which are antagonistic to good fermentation. Thus Kossowicz<sup>23</sup> found that the presence of large amounts of potash salts retards fermentation by diminishing the multiplication of yeast cells;

though, if not in too excessive quantities, the yeast may become acclimatized.

(3) As to the remaining essential elements, iron, magnesia, lime, and sulphates, they are required in very small quantities, and the molasses contains more than a sufficiency of them.

4. Bacterial Infection.—All the work was performed under strictly aseptic conditions, and the absence of bacteria from the fermentation was proved from time to time by means of sub-cultures; the presence of bacteria would be indicated by a considerable increase in the acidity of the wash over the initial acidity of the wort. There is always some increase due to the yeast itself; Verbríese<sup>24</sup> defines as the limit of increase of acidity, in good fermentation, 0.6 grams per liter as sulphuric acid. The differences in our fermentations slightly exceeded this limit, as may be seen from Table X, where the acidities are expressed as grams of sulphuric acid per 100 cc.

TABLE X.  
COMPARATIVE ACIDITIES.

Wort.	Wash.	Wort.	Wash.	Wort.	Wash.
.196	.314	.314	.352	.271	.314
.314	.392	.209	.314	.300	.392
.235	.352	.209	.314	.209	.274
.186	.314	.352	.431	.209	.274
.196	.274	.209	.235	.241	.274
.204	.392	.209	.314	.209	.274
.220	.314	.241	.314	.308	.352

The average acidity of the worts is .240 and of the wash .323, an increase of .083, or .83 per liter, which exceeds the limit named by Verbríese.

Bacteria do not thrive in acid media, and this fact is taken advantage of in fermentation practice by the addition of sulphuric acid to the wort at the rate of 10 gallons to 1,000 gallons. Another effective bactericide is hydrofluoric acid or its salts. In order to work effectively, a yeast must be acclimatized to the presence of these compounds by first growing it in solutions containing small quantities and gradually increasing the amount. Effront,<sup>24</sup> to whom this method is due, has succeeded in cultivating yeasts in worts containing 36 grams of hydrofluoric acid per 100 liters. In Argentina,<sup>25</sup> hydrofluoric acid was found to be of considerable assistance, killing all bacterial infection, although it retarded fermentation. Klöcker<sup>26</sup> states that yeasts in hydrofluoric acid media have but feeble powers of budding, but great



fermentative power. The usual distillery practice is one ounce to 60 gallons. Table XI gives results of fermentations carried on in the presence of sulphuric acid and acid ammonium fluoride in the proportion of 1 cc. and .1 gram per liter respectively, Race II, as usual, being the yeast employed.

TABLE XI.

Addition to Wort.	Spec. Gravity of Wort.....	Sugars Grams per 100 cc.....	Alcohol % Vol....	Alcohol % Total Sugars.....	Acidity Grams Sul- phuric Acid per 100 cc.		
					Wort.	Wash.	In- crease.
None.....	1.0695	9.92	5.45	85.4	.209	.274	.065
Sul. Acid....	1.0695	9.92	5.55	86.8	.314	.394	.080
None.....	1.0568	7.76	4.18	83.6	.139	.274	.135
Am. Fluoride	1.0568	7.76	4.13	82.6	.149	.235	.086
Am. Fluoride	1.0568	7.76	4.08	81.6	.149	.274	.125

It is thus apparent, that with two safeguards against infection, viz., sterility and presence of substances fatal to bacterial development, there is still a decided increase in the acidity of the wash. This, however, would account for a very small proportion of the sugars unaccounted for, and is doubtless due to the nature of the yeast itself and its natural products.

5. Effect of Aeration.—All of the fermentations heretofore reported were in worts containing no air, or only that absorbed in the Carlsberg vessel during the cooling of its contents and withdrawal of portions for fermentation. Nageli and other authors have shown that in the presence of an abundance of oxygen the same amount of alcohol is produced by yeasts as before. Aeration causes more rapid multiplication of the yeast cells, but at the expense of some of the sugar in the fermenting medium.<sup>27</sup> Aeration is, accordingly, best used in connection with the preparation of a mother yeast, supplying in this way a large number of vigorous yeast cells to the wort to be fermented. To determine the relative yields with and without aeration, wort was deprived of its air by heating in an autoclave. Two lots were fermented with a slow stream of air passing through a sterile cotton plug and thence through the wash for twenty-four hours after adding the yeast; the other two without aeration being started at the same time. The results in Table XII show that the results were practically identical, with the exception that in the second trial, the fermentation in the aerated lot was finished 24

hours ahead of that which contained no air. This can be explained by the effect of the oxygen in the air on the multiplication of the yeast, resulting in a vigorous growth thereof and a larger number of yeast cells.

TABLE XII.  
EFFECT OF AERATION.

	Time, Hours.....	Specific Gravity of Wort.....	Attenuation.....	Sugars Grams per 100 cc.....	Alcohol % Vol....	Alcohol % Total Sugars.....
Not aerated...	144	1.0690	37.1	9.27	5.20	87.1
Aerated.....	144	1.0690	37.1	9.27	5.19	86.9
Not aerated...	96	1.0699	39.3	9.98	5.31	82.7
Aerated.....	72	1.0699	39.3	9.98	5.29	82.4

6. Effect of Stimulants.—Several substances have been found to have a stimulating action on the growth of the yeasts, thus exerting a favorable effect on fermentation. The action of ammonium salts has already been mentioned. Kayser and Marchand<sup>28</sup> report that when manganese sulphate or other salts of manganese are added to a wort at the rate of one to one and a half grams per liter, there is an increase in the alcohol yield of 2 per cent. by volume, the alcohol increasing in proportion to the manganese added,<sup>29</sup> while the glycerol and volatile acids diminish. Gimel<sup>30</sup> states that one part of stannous chloride in 10,000 wort increases the yield 4 per cent. These salts were tried with our molasses, alone and along with ammonium fluoride. Race II was first started in worts containing very small quantities of the stimulants, the amounts thereof being gradually raised until the proportions were

Acid Ammonium Fluoride..... 0.1 gram per liter

Manganese Sulphate ..... 1.0 " " "

Stannous Chloride ..... 0.1 " " "

Table XIII shows that there was no improvement in the action of the yeast with the exception where manganese sulphate increased the alcohol yield one per cent. by volume when used alone, but did not improve it when used with ammonium fluoride. These results are taken from a series of three fermentations.

TABLE XIII.  
EFFECT OF STIMULANTS.

Salts Added.	Specific Gravity of Wort.....	Attenuation.....	Total Sugars Grams per 100 cc.....	Alcohol % Vol....	Alcohol % Total Sugars.....
Acid Ammonium Fluoride.....	1.0568	30.9	7.76	4.13	82.6
Manganese Suphate.....	1.0568	30.1	7.76	4.23	84.6
Stannous Chloride.....	1.0568	31.1	7.76	4.18	83.6
Acid Am. Fluo. & Mang. Sul..	1.0568	30.8	7.76	4.10	82.1
Acid Am. Fluo. & Stan. Chl....	1.0568	31.6	7.76	4.18	83.6
None.....	1.0568	30.8	7.76	4.18	83.6

COMPARISON OF THE RESULTS OBTAINED WITH HAWAIIAN  
MOLASSES AND THOSE OBTAINED ELSEWHERE.

One of us, having had a somewhat extensive experience with the fermentation of molasses elsewhere, was struck by the very low attenuation and yield given by the majority of Hawaiian molasses; in Demerara, wash set at 1.060 seldom has a final density of more than 1.020, and in certain cases may reach to as low as 1.015. The Hawaiian molasses, with which we worked under aseptic conditions, never gave so high an attenuation as this. Thinking that the low attenuation of the Hawaiian molasses might possibly be due to a faulty fermentation, we obtained, through the kindness of Mr. W. M. B. Shields of Demerara, samples of exhausted molasses from this locality and fermented them under the same conditions under which we had treated the Hawaiian molasses.

The molasses from Demerara were of the composition shown below:

	Molasses A.	Molasses B.
Brix .....	82.85	82.85
Total Solids.....	77.50	80.25
Sucrose, Direct Polarization.....	36.50	35.00
Sucrose, Clerget.....	38.30	34.90
Purity, Apparent.....	44.05	42.20
Purity, True.....	49.40	43.50
Glucose .....	19.63	32.52
Glucose Ratio.....	51.20	93.20
Ash .....	8.23	5.17

For the purpose of fermentation, these molasses were diluted to a specific gravity of about 1.060. At this density, molasses B contained 13.19 grams total sugars per 100 cc., and the fermentation was extremely slow. A further fermentation was therefore carried on with a weaker wort. The results are given in Table XIV.

TABLE XIV.

## FERMENTATION OF DEMERARA MOLASSES.

	Time, Hours.....	Specific Gravity.		Attenuation.....	Sugars Grams per 100 cc.....	Alcohol % Vol.....	Alcohol % Total Sugars.....	Gallons U. S. Proof Alcohol per Gallon Molasses.....
		Wort.	Wash.					
A	120	1.0604	1.0128	47.6	11.54	6.45	86.8	.92
A	120	1.0604	1.0104	50.0	11.54	6.70	90.2	.97
B	168	1.0607	1.0110	49.7	13.19	7.03	82.8	1.00
B	72	1.0445	1.0048	39.7	9.67	5.33	85.6	1.04

A low attenuation being obtained with these molasses shows that the action of the yeast was not at fault, and the difference in the attenuation between Hawaiian and Demerara molasses is readily explained from their composition. Typical Hawaiian molasses, though of similar purity to well exhausted molasses from other localities, yet contain much less total sugars, i. e., sucrose and reducing sugars, and hence, when set at the same density, will give a less attenuation due to the less quantity of fermentable matter present.

## COMPARISON OF RESULTS WITH ADVENTITIOUS FERMENTATION AND UNDER PURE CULTURE.

The results obtained in the section immediately above afford a comparison of the difference in results when working under ordinary conditions and under conditions of pure culture. In actual practice and under pure culture the molasses A gave results as shown below:

	Actual Results.	Pure Culture.	
Wash set at.....	1.0600	1.0604	1.0604
Final Density.....	1.0200	1.0128	1.0104
Attenuation.....	40.0	47.6	50.0
Proof Spirit % Calculated from Attenuation*	9.36	11.14	11.70

That is to say, that under pure culture methods of working an increased yield of 22% of alcohol can be expected over that obtained when working under the conditions usually prevailing in tropical cane-sugar distilleries.

A further comparison is offered in Table XV where results from another factory fermentation and from pure culture are given.

TABLE XV.

## COMPARISON OF FACTORY AND LABORATORY RESULTS.

	Factory.	Laboratory.			
		Molasses A.		Molasses B.	
Wash set up at.....	1.0630	1.0604	1.0604	1.0607	1.0445
Wash Attenuation to.....	1.0210	1.0128	1.0104	1.0110	1.0048
Attenuation.....	42.0	47.6	50.0	49.7	39.7
Proof Spirit by Analysis*..	9.58	11.20	11.73	12.30	9.33
Pounds Glucose per Gallon					
Proof Spirit.....	14.1	10.28	9.80	10.75	10.41

We may conclude then, that the yields obtained in these experiments are at least equal to those possible when working under factory conditions with pure culture yeasts and sterile precautions. In the following calculations it will be considered that from each gallon of the average molasses of these islands there may be obtained in the fermentation 0.77 gallon of proof spirit or .405 gallon of 95 per cent. alcohol. In other words, there are required:

- 1.30 gallons molasses to 1 gallon proof spirit.
- 2.47 gallons molasses to 1 gallon 95% alcohol.
- 2.60 gallons molasses to 1 gallon absolute alcohol.

## FERTILIZING VALUE OF MOLASSES BEFORE AND AFTER FERMENTATION.

The residue or wash after distilling off the alcohol is called lees, or usually, when referring to beet molasses, vinasse. The vinasse is largely conserved for its fertilizing value by concentration under vacuo, and there have been published many devices for the most economical manner of conducting this operation. There has been on the local market a fertilizer derived from this source. It is of a black color, fine granular in appearance, and contains

\* These figures represent English proof spirit, which contains 57.06 per cent. alcohol by volume.

3.7 per cent. nitrogen and 16.8 per cent. potash. One process<sup>32</sup> after partial concentration acidifies with sulphuric acid, and after a further concentration, part of the potash crystallizes out as sulphate. The residual liquor is then evaporated to dryness, yielding a material containing 5 to 7 per cent. of nitrogen and 6 to 7 per cent. of potash. A still more complicated process is worked in some plants in Germany,<sup>33</sup> where by dry distillation of the concentrated vinasse, a fourth of the nitrogen is recovered as sodium cyanide and an equal amount as ammonium sulphate. The remaining half is lost, whilst the coke is sold to other establishments to be worked up into potash. This process, however, requires an extensive and intricate plant, and presents many complicated problems. It has not, as far as we know, been investigated with regard to the residue from cane molasses fermentations.

The potash in the molasses remains unchanged during fermentation, and is all to be found in the lees and sedimentary yeast. If this were evaporated and charred, the potash could all be extracted and crystallized either as a mixture of carbonate, chloride, and sulphate, or as sulphate, according to whether or not it was treated with sulphuric acid before burning. In this case all the nitrogen, which is more valuable pound for pound than the potash, would be lost.

Two Hawaiian molasses before and after fermentation gave the results as given in Table XVI, the figures representing grams of nitrogen per liter.

TABLE XVI.  
NITROGEN BEFORE AND AFTER FERMENTATION.

	Wort.	Wash.	Wort.	Wash.
Nitrogen as Ammonia.....	.0385	.0093	.0154	.0070
Nitrogen, Albuminoid.....	.0329	.0354	.0189	.0161
Nitrogen, Amido*.....	.8106	.7715	.7861	.6069
Nitrogen in Yeast.....	....	.0444	....	.1674
Nitrogen, Total.....	.8820	.8606	.8204	.7974

Then nitrogen in the yeast is mostly albuminoid, and has been formed in the metabolism of the yeast at the expense of the ammonia and amide nitrogen of the molasses. A method of preparing the yeast residue for use as a fertilizer has been published by Schidrowitz and Kaye,<sup>34</sup> which, by treating it with sulphuric acid and drying with chalk, gives a mass containing 8 to 9 per cent. ammonia.

With a distillery situated adjacent to cane fields, the lees could

\* By Difference.

be used directly as a fertilizer, by being conducted thereto either by gravity or pumps, of course after liming to correct the excessive acidity. The fermentation industry can, however, be carried on most profitably in large establishments, and a centralized distillery might therefore produce much more residual lees than could be disposed of to advantage in the above manner. In order to transport the fertilizing ingredients, it would, of course, be necessary to concentrate the lees.

The concentrated and dried lees is not easy to handle. On account of the large amount of caramel therein, which is extremely deliquescent, and also the considerable quantities of chlorides of the alkaline earths, which are very hygroscopic, the finished concentrate takes up water rapidly from the air and soon becomes pasty. By proper treatment, especially with sulphuric acid, this character can be considerably modified, giving a product which is relatively easy to handle. Kestner<sup>35</sup> proposes that vinasse for use as fertilizer should be concentrated, dried, and mixed with some absorbent, preferably peat, which gives a product of suitable mechanical condition, the greater cost of which is compensated from the increased profits derivable from its sale as fertilizer.

Two lots of lees from Hawaiian molasses were evaporated first on a water bath, then in a drying oven, until perfectly dry. One lot received no treatment, the other was acidulated with sulphuric acid. The first lot lost its good condition after two days exposure to the air, but the second, even after the lapse of several weeks, showed no very great tendency to become pasty and unmanageable.

TABLE XVII.  
ANALYSIS OF DRIED LEES.

	Non-Acidulated.			Acidulated.		
	Per cent.....	Grams per Liter of Lees.....	Pounds per Gal. Molasses.....	Per cent.....	Grams per Liter of Lees.....	Pounds per Gal. Molasses.....
Dry Matter.....	....	90.0	3.735	....	98.14	4.073
Loss on Ignition.....	62.76	56.48	2.344	60.75	59.62	2.474
Potash.....	15.71	14.13	.587	13.15	12.91	.536
Nitrogen.....	1.01	.91	.038	.93	.92	.038
Phosphoric Acid.....	.45	.41	.019	.50	.49	.020

To the totals in the lees must be added the nitrogen, phosphoric acid, and potash in the yeast sediment. The last was not determined, but as this particular molasses was extremely high in this element, the results as given in Table XVIII will not be far from the average to be expected when handling a mixture of molasses of the extremely divergent composition that obtains from the different mills. Table XVIII is calculated from the average of the results of Table XVII.

TABLE XVIII.  
FERTILIZING INGREDIENTS IN LEES.

	Per cent.	Grams per Liter Lees.	Pounds per Gallon Molasses.
Dry Matter in Lees.....	....	94.07	3.904
Potash.....	14.43	13.574	.563
Nitrogen in Dried Lees.....	.97	.912	.038
Dried Yeast.....	....	1.300	.054
Nitrogen in Yeast.....	8.12	.106	.004
Total Nitrogen.....	....	1.018	.042
Phosphoric Acid in Lees.....	.48	.452	.018
Phosphoric Acid in Yeast.....	4.59	.060	.002
Phosphoric Acid Total.....	....	.512	.020

#### COST OF MANUFACTURE OF ALCOHOL.

The cost of manufacture is naturally affected by many conditions, such as the price of labor, fuel, containers, freight, etc. In Demerara, the cost of 95 per cent. alcohol in a distillery producing 100 gallons of spirit per hour is about 5 cents per gallon, exclusive of containers, fuel, and freight. In the United States, Heyn<sup>36</sup> estimates the cost of manufacturing alcohol at 8 cents per gallon, excluding the cost of the molasses. J. N. S. Williams<sup>37</sup> in his report as chairman of Committee on Utilization of By-products, stated to the Hawaiian Sugar Planters' Association that it would cost 10.2 cents per gallon, exclusive of cost of molasses. In Cuba,<sup>38</sup> the cost is about 10 cents per gallon, while Wiley<sup>39</sup> places the cost at something under this amount. It may be safely assumed, then, that the cost of manufacturing alcohol, not including the purchasing of the raw material, will not exceed 10 cents per gallon.

#### COST OF RECOVERING FERTILIZER ELEMENTS.

It is a harder matter to establish definite figures as to what will be the expense attached to a plant for recovering the fertilizing



materials in the lees in such form that it may be transported. It has been the practice in some places to run the lees into large ponds, and afterwards digging out the soft black mud for its fertilizing contents; this is not very economical, and at best an extremely unsanitary proceeding. Another method is described by one of us<sup>40</sup> as follows: "With regard to liquid manuring, the great objection is the bulk of material to be dealt with, so that means to collect the valuable constituents are naturally looked for. Lees, when allowed to settle, give a considerable deposit, and, when treated with lime, give a copious precipitate. It was found by direct experiment that, completely to precipitate 1,000 gallons of lees, 150 pounds of commercial temper lime were necessary. After treatment lees that contained .0104 pound nitrogen per gallon, now contained .00406 pound per gallon, showing that about 60 per cent. of the nitrogen was precipitated. On filtration a sludge in volume about 15 per cent. of the lees treated was obtained; the precipitated matter when dry contained 3.82 per cent. of nitrogen. The treatment of lees in this way would require no expensive outlay, the sludge obtained might be used direct or passed through filter presses and formed into a solid cake. The sludge filters easily, and, when dry, forms a dirty gray, easily pulverized material; the cakes would hold about 50 per cent. of water and would contain about 19 per cent. nitrogen. This method of treatment would still leave the potash to run to waste."

The method we shall consider is that of concentration. The cost of evaporation will vary greatly according to the density at which the wort is set up. It has been shown that some yeasts will act equally well in worts containing from 9 to 12 per cent. of sugars, that is, at densities of wort varying from 1.065 to 1.000; and with no great diminution of effectiveness even at a density of 1.10 with 14.6 per cent. of sugars. By selection of a yeast working properly in such a concentration, not only will the cost of evaporation of the lees be smaller, but that of distillation of the spirit will be materially lessened.

Another manner in which it was thought it might be possible to economize on the evaporation incident to the recovery of the fertilizing elements, was to use lees for diluting the molasses for fermentation instead of water. Two equal weights of molasses were diluted, one with 500 cc. of water and the other with 500 cc. of lees. The density of the lees was 1.0349, acidity equivalent to .302 gram sulphuric acid per 100 cc., and the content of reducing bodies equal to .62 gram per 100 cc. The results of three series of fermentations of each are given in Table XIX.

TABLE XIX.

	Molasses and Water.			Molasses and Lees.		
	1	2	3	1	2	3
Time, Hours.....	166	120	96	166	144	144
Specific Gravity of Wort.....	1.0755	1.0755	1.0755	1.1016	1.1016	1.1016
Attenuation.....	40.9	41.5	40.9	43.1	42.6	40.1
Sugars. Grams per 100 cc.....	10.48	10.48	10.48	11.14	11.14	11.14
Alcohol % Volume.	5.59	5.53	5.88	5.34	5.36	5.45
Alcohol % Sugars in Molasses....	82.6	81.9	86.9	79.1	79.5	80.8
Acidity of Wort..	.157	.157	.157	.431	.431	.431
Acidity of Wash..	.314	.274	.314	.510	.510	.510

The average alcohol content was 5.67 per cent. with water, and 5.38 with lees, a loss of 5 per cent. of the alcohol. In the mixture with water there were four per cent. more of the sugars of the molasses fermented than in that with the lees.

A lees, of the analysis given on page . . , contains 94.07 grams dried matter to the liter, or from each liter there must be evaporated over 906 grams of water. Figured to gallons, this would mean 78 pounds of dry matter per gallon, and an evaporation slightly over 8.25 pounds for each gallon of lees. A pound of coal will evaporate 8 pounds of water, and in a triple effect approximately three times that quantity. As evaporation of lees could be only partially accomplished in vacuo, and a final drying would have to be effected in open vessels, it will be safer to assume that there will be required a pound of coal for two gallons of lees. A short ton of coal will therefore concentrate 4,000 gallons of lees. The value of the residue, from the figures of Table XVIII will be:

Potash, 450 pounds at 6 cents.....	\$27.00
Nitrogen, 16 pounds at 20 cents.....	3.20
	<hr/>
	\$30.20

With coal at ten dollars per ton, this leaves a wide margin for operating expenses, bagging, interest, and a reasonable profit.

#### VALUE OF MOLASSES AS ALCOHOL AND FERTILIZER.

Price of Alcohol. Denatured alcohol sold at Peoria in 1907<sup>41</sup> in lots of 5 or more barrels for 35 cents per gallon. Allowing ten cents per gallon for the denaturing, the alcohol from

the molasses would be worth 25 cents per gallon. On this basis, and with potash, nitrogen, and phosphoric acid worth 6, 20, and 2 cents per pound respectively, the following estimates of the value of the molasses have been made, using the molasses as described on page .. as the raw material.

This molasses, with a specific gravity of 1.51, will contain in 1,000 gallons:

Total Solids .....	10,630	pounds
Total Sugars .....	6,231	"
Solids not Sugar .....	4,399	"
Potash .....	615	"
Nitrogen .....	80.5	"
Phosphoric Acid .....	14.0	"

If this molasses is diluted with six times its volume of water, the wort as set up will be composed as follows, the contraction due to mixing water and molasses being neglected:

Gallons of Wort.....	7,000
Specific Gravity .....	1.0730
Sugars, Grams per 100 cc.....	10.7

If the sugars yield 83 per cent. of the theoretical amount of alcohol, this will yield 421 gallons of 95 per cent. alcohol.

In order to obtain the potash, nitrogen, and phosphoric acid, it will be necessary to evaporate a volume of water about equal to that of the wash, on account of the condensation of steam in the column during distillation. By this operation, all the potash and phosphoric acid will be recovered, but during the concentration some of the nitrogen may be lost. In the molasses, the nitrogen exists in the proportion of .131 to 1, while in the lees reported in Table XVIII, this ratio became .074 to 1. We could therefore expect from 1,000 gallons of the molasses 46 pounds of nitrogen.

The returns from such an operation would be about as follows:

421 gallons 95 per cent. alcohol at 25 cents. .	\$105.25
615 pounds of potash at 6 cents.....	36.90
46 pounds of nitrogen at 20 cents.....	9.20
14 pounds of phosphoric acid at 2 cents...	.28

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\$151.63

The expenses attached to this production would be approximately:

421 gallons alcohol at 10 cents.....	\$42.10
Evaporation of lees (Fuel at \$10.00 per ton). .	17.25
Labor, bags, etc., on above, say.....	.50

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\$59.85

Leaving a profit of \$91.78, at which rate the molasses will have been worth 9.2 cents per gallon.

If we now have the molasses set up at a higher density, and achieve an equally good result in the fermentation, the figures will be quite different. If the wash is set up with four and a half times its volume of water, the wort will be:

Gallons .....	5.500
Specific Gravity .....	1.0927
Sugars, Grams per 100 cc.....	13.60

The operating expenses would now be reduced as to the fuel for concentrating the lees, thus:

421 gallons alcohol at 10 cents.....	\$42.10
Evaporation of lees (fuel at \$10.00 per ton) .	13.75
Labor, etc.....	.50

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\$56.35

Or a profit of \$95.28, whence a value to the molasses of 9.5 cents per gallon.

The previous calculations were based on possible results from a molasses from one source. We will now estimate the yield from molasses of the average composition of the 25 molasses reported in Table III and their yield in alcohol as given in Table IV. Such an average would be:

Brix .....	84.47
Specific Gravity .....	1.46
Total Sugars per cent.....	51.68

Average yield .405 gallon 95 per cent. spirit per gallon molasses.

The potash and phosphoric acid contents will be taken as the same as the average of 27 Hawaiian molasses analyzed at this Station in 1906,<sup>8</sup> viz., 3.99 to .21 per cent. respectively. Such a molasses would then contain 486 pounds of potash and 26 pounds of phosphoric acid per 1,000 gallons. The average nitrogen content of the molasses treated in this present bulletin is .64 per cent., identical with that of the molasses used in the calculations preceding. It may then be safely assumed that the amount recovered will be the same.

Setting the wash up with six times its volume of water, and allowing five per cent. loss of alcohol during manufacture, there would result from the fermentation of 1,000 gallons of molasses:

385 gallons 95 per cent. alcohol at 25 cents..	\$ 96.25
486 pounds potash at 6 cents.....	29.16
26 pounds phosphoric acid at 2 cents.....	.52
47 pounds nitrogen at 20 cents.....	9.40

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\$135.33

Against this would be the following expense:

385 gallons alcohol at 10 cents.....	\$38.50
Recovery of fertilizer.....	17.75
	<hr/>
	\$56.25

Whence the profit of \$79.08 would give a value to the molasses of 7.9 cents per gallon.

Now, if the molasses is set up with  $4\frac{1}{2}$  times its volume of water, against returns of \$135.33 as before, will be expenses as follows:

385 gallons alcohol at 10 cents.....	\$38.50
Recovery of fertilizers.....	14.25
	<hr/>
	\$52.75

Leaving a profit of \$82.58, and a value to the molasses of 8.3 cents.

It is felt that the figures given above are quite conservative. It is very probable that by careful selection and acclimatization, a yeast will be found that will not only give as good yields in practice as are achieved in the laboratory, but will work equally well in worts of sufficiently high density to make the recovery of the fertilizing ingredients most economical. Likewise it should be possible by careful handling of the lees, to recover a far greater percentage of the nitrogen than we succeeded in doing with our laboratory apparatus.

A very important item of expense not so far taken into account is that of the carriage of the molasses to the distillery. This will no doubt amount to a considerable proportion of the expense column, but should not exceed two cents per gallon. Making a further allowance for interest on the investment and depreciation, and with molasses yielding a final value of five cents per gallon, there would result to the plantations on 10,000,000 gallons a return of a half million dollars per annum. Thus, even with a considerable drop in the price of raw spirit, a liberal margin of profit is still left.

#### USES OF DENATURED ALCOHOL.

An immense vista of manufacturing possibilities has been opened by the enactment of the law permitting the use of tax-free alcohol, such as that of smokeless powder, celluloid, artificial silk, collodion, and varnishes, all of which are industries consuming immense quantities of spirit. To these islands, however, the most probable benefit will be that of supplying a substitute for kerosene and gasoline as source of light, heat, and motive power.

The supply of the petroleum products is directly dependent on the amount existing in the earth and cannot be increased by any known human agency. That of alcohol is controlled directly by human activity and will be increased or diminished according to the demand. There were in 1907 at least 300,000 explosion motors in use, each engine averaging eight horse power and consuming about ten gallons of gasoline a day.<sup>5</sup> This number is constantly increasing; and as the demand for gasoline likewise grows greater and no additional sources of supply are developed, the price of gasoline will naturally become higher. Alcohol can be produced wherever crops grow. Its production entails no exhaustion of the soil, as only the elements derived from air and water enter into its composition. When the production of the petroleum products cannot keep pace with the ever increasing demand, those countries furthest removed from the sources of supply will first feel the effect of the increased cost, owing to the distance from the market and expense of transportation. We have here in Hawaii, in one of our waste products, that which will contribute in a large measure towards the supplying of a necessary and efficient substitute.

*Light.*—As a producer of light, alcohol easily outranks kerosene and is inferior only to gas. Tests made by the Electrical Testing Co. of New York City, gave results as follows:

Lamp.	One gallon will last	Candle Power.	Candle Power, Hours.
Alcohol....	57 hours, 5 minutes.	30.35	17.32
Oil.....	28 hours, 40 minutes.	30.8	8.83

A German firm reports the following results, taking alcohol at 30 cents and kerosene at 18 cents per gallon:

	Cents per 16 candle power hour.
Alcohol .....	.0008
Gas .....	.0006
Electricity .....	.0014
Kerosene .....	.0010

With alcohol costing twice as much as kerosene, these figures show the expense of operation to be about the same. The alcohol lamp has the advantages of fouling the atmosphere less than half what the kerosene lamp does; it is safer, since burning alcohol can be extinguished by water; cleaner, requires less attention, and gives a uniform light.

*Fuel.*—As a fuel for heating or cooking purposes, the alcohol is apparently not as efficient as the oil products, when judging from the theoretical amount of heat furnished by each. Never-

theless, in practice the relative efficiency of the fuels is such that the alcohol costs only one-fifth more than the gasolene.

*Motors.*—As a substitute for gasolene in internal combustion engines, gasolene at its present price is considerably more efficient than alcohol, although in Germany, with alcohol at 29 cents per gallon, a large number of alcohol motors are used, particular in agricultural operations. Very complete descriptions of such appliances are to be found in "Denatured or Industrial Alcohol," R. F. Herrick, and "Industrial Alcohol," J. K. Brachvogel. Among the advantages of alcohol are the facts that it is far less dangerous than the readily inflammable petroleum products, the exhaust odors are not as disagreeable, there are no clogging products, the explosive mixture will stand a higher degree of compression,\* and it can be relied upon to be of a uniform composition. The attention of engineers has not been long engaged in the investigation of alcohol as a motive power, and we can confidently anticipate that before long, aided perhaps by an increase in the cost of gasolene, motors will have been devised for alcohol which, besides the advantages enumerated above, will also possess that of being operated at an equal or less cost than those of gasolene.

#### EXPLANATION OF TERMS.

*Attenuation.*—The difference between the specific gravity of the wort and completely fermented wash, the decimal point being removed three places to the right. For each five degrees of attenuation, there may be expected about 1.33 gallons of proof spirit per gallon of wash.<sup>43</sup>

*Adventitious Fermentation.*—That which is induced by yeasts existing in the air, on the cane or on the sides and bottoms of vats used in a previous fermentation which was started by yeasts from the air or cane.

*Denaturing.*—This is the process of rendering alcohol unsuitable for drinking, and, as defined by Wiley<sup>44</sup> consists, essentially, in adding to the alcohol a substance soluble therein of a bad taste or odor, or both, of an intensity which would render it impossible or impracticable to use the mixture as a drink.

*Lccs.*—The residue after the alcohol has been distilled from the wash.

*Proof Spirit.*—The United States definition is "that alcoholic liquor which contains one-half its volume of alcohol of a specific gravity of .7939 at 60° Fahrenheit,"<sup>45</sup> in other words, half its

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\* The compression of alcohol vapor may be safely carried to 200 pounds per square inch, while that of gasoline cannot endure more than 80 pounds without danger of premature explosion.

volume of absolute alcohol. English proof spirit contains 57.06 per cent. alcohol by volume and is of specific gravity .9198 at 15.5° C.

*Setting Up.*—This signifies the dilution of the molasses previous to pitching with yeast.

*Wash.*—The dilute molasses after the yeast has been added.

*Wort.*—The dilute molasses before the addition of the yeast.

#### DESCRIPTION OF THE ORGANISMS STUDIED.

Comparatively little work has been done in the way of describing the organisms to which the fermentation of cane sugar molasses is due. The most detailed work is that due to Prinsen-Geerligs and Went<sup>7</sup> who isolated from Raggi or Java yeast a *saccharomyces* which they named *S. vordermannii*. The yeasts occurring in Jamaica distilleries have been studied first by Greg<sup>45</sup> and, more recently, by Allan;<sup>46</sup> both of these observers noted the presence of fission yeasts in Jamaica distilleries, and the latter ascribes to their influence the aroma with which a Jamaica rum is connected. Perrault<sup>47</sup> failed to observe fission yeasts in Demerara and in Jamaica distilleries, but observed them in distilleries in the Leeward Islands; one of us has never observed fission yeasts in a long experience in Demerara distilleries.

With the exception of the yeast obtained from Peru, all the yeasts studied by us were budding yeasts, very close to *S. vordermannii*; differences were noted, e. g., that one we have described as Natal No. 1 was uniformly of larger size than any of the others; we are inclined, however, to regard these differences as varietal and not as specific, and hence, in place of giving new names, as species, to the budding yeasts that we have isolated, we prefer to refer them all to *S. vordermannii*, as this variety or species has received a general acceptance in the literature.

The yeast obtained from Peru was a fission yeast; of fission *Schizosaccharomyces mellacei*, isolated by Greg from Jamaica yeasts, which are of less frequent occurrence than budding yeasts, we have found in the somewhat restricted literature at our disposal, notices of only the two following:

*Schizosaccharomyces pombe*, isolated from Kaffir millet beer in South Africa.

*Schizosaccharomyces mellacei*, isolated by Greg from Jamaica distilleries and presumably the form studied by Allan.

*Schizosaccharomyces octosporus* isolated by Beijerinck from currants.

*Schizosaccharomyces comesii* isolated by Cavara from millet.

Fission yeasts have also been noticed by Perrault<sup>47</sup> (in distilleries in the Leeward Islands), who mentions that most of those that were observed formed four spores.



The vegetative form of the yeast we isolated from Peru seems to be distinct from the form illustrated by Lindner<sup>26</sup> as typical of *Sch. pombe*, and also from *Sch. mellacei* as described by Jorgensen, but in view of the limited literature at our disposal we do not feel justified in making a new species for this yeast.

From the specimen of yeast obtained from Natal, we isolated an organism with the following characteristics: on agar plates it formed a surface growth, at first smooth and eventually becoming extremely crinkled; examined under the microscope, two forms of cells were observed; some resembling typical *saccharomyces* cells and other elongated cells with generally two highly refractive vacuoles; on agar plates, a fringe is seen to form eventually, consisting of filaments sometimes united in bundles and with the cells above mentioned interspersed in the filaments. In beer wort and in molasses wort, a film was formed resembling that obtained in an acetic fermentation.

These are the characteristics of a *Monilia*; Went and Prinsen-Geerligs<sup>7</sup> have already isolated and described a *Monilia* from Raggi or Java yeast, and have named it *Monilia javanica*. We obtained, from a sample of Raggi, this organism which is close to the one we have isolated from Natal. The cultural characteristics on agar plates were, however, different from those from Natal, giving a much more crinkled growth, and a further difference which will appear later. In view of the limited literature at our disposal we do not, however, feel justified in making a new species for this organism.

Drawings of the "yeast form" of *Monilia javanica* from our cultures are shown in Plate II, Figs. 4 and 9, from preparations in beer wort agar and in beer wort, both thirty-six hours old; the corresponding forms of the Natal species are shown in Plate I, Fig. 2, and in Plate II, Fig. 2.

A point of very considerable interest arose in the study of the *Monilia* we obtained from Natal; it was observed to give a fruity smell reminiscent of the very finest Jamaica rum. We accordingly grew this in pure culture in molasses wort; there were formed 7,558 parts of ethers as ethyl acetate per 100,000 of alcohol; at the same time a pure culture of yeast gave only 18 parts of ethers as ethyl acetate per 100,000 of alcohol. The flavor of rum is by some connected with the presence of butyric acid bacteria, the butyric acid formed interacting with the alcohol to form ethyl butyrate; by others, fission yeasts are held responsible. We demonstrated that the ethers formed by this *Monilia* were mainly ethyl acetate and butyrate. We suggest that to this or to some closely allied form is due the peculiar fruity odor of high class rums.

Below are found brief descriptions of the yeasts studied.

## CUBA.

*Beer wort, 36 hours old*; cells oval, 6.3 to 9 microns long by 5 to 6.5 microns wide. Plate I, Fig. 7.

*Agar beer wort plate culture, 36 hours old.* Colonies circular glistening opaque, edge entire, about 2 mm. diameter; cells oval or pointed with one or two vacuoles, generally smaller than in beer wort, 5 to 8 microns long by 3 to 4.5 microns wide. Plate II, Fig. 5.

*Sediment from beer wort, 10 days old.* Large granular cells, oval to circular in shape, from 7 to 9 microns long by 6 to 7 microns wide; elongated cells, sometimes arranged in chains, 14 microns long by 3.5 to 4 microns wide not uncommon. Plate III, Fig. 2. On shaking the sedimentary deposit, it becomes distributed through the wort and settled slowly.

*Sporulation.*—Spores were formed in 36 hours at 32° C. on gypsum blocks; two, three and four spores were formed in one cell, four being the most frequent number; sporulation occurred more abundantly with this yeast than with any other. The form with the spores arranged as at the angles of a rhombus was frequent, and was observed in no other of the yeasts examined. Plate IV, C.

*Propagation* occurred by a terminal bud and less frequently by a lateral one.

*Physiology.*—Growth was very rapid at 32° C., and very slow at 20° to 25° C., our ordinary laboratory temperature. Ferments saccharose, maltose, dextrose and levulose.

## DEMERARA.

*Beer wort, 36 hours old*; cells oval, 5.5 to 7.5 microns long by 4 to 5 microns wide. Plate I, Fig. 5.

*Agar beer wort plate cultures, 36 hours old*; colonies as for the Cuban yeast; cells generally with only one vacuole, 6.5 to 7.5 microns long by 4.5 to 5.5 microns wide. Plate II, Fig. 7.

*Sediment from beer wort, 10 days old.* Granular, irregularly shaped cells from 5.5 to 7 microns long by 4 to 5 microns wide. On shaking, behaved like the Cuban yeast. Plate III, Fig. 8.

*Sporulation.*—Spores were formed on gypsum blocks in 72 hours at 32° C., the sediment from a 36-hour beer wort fermentation being used; two, three or four spores were formed, two spores being most common; comparatively few of the cells sporulated. Plate IV, D.

*Propagation and Physiology.*—As for Cuba.

## JAVA.

*Beer wort, 36 hours old.* Cells round to oval, 6 to 7 microns long by 5 to 5.5 microns wide. Plate I, Fig. 1.

*Agar beer wort plate culture, 36 hours old.* Colonies as for the Cuban yeast; cells generally with only one vacuole, oval or elongated in shape; from 6.5 to 8.5 microns long by 2 to 4 microns wide. Plate II, Fig. 8.

*Sediment from beer wort, 10 days old;* cells granular, oval to elongated in form; 5.5 to 7 microns long by 2.5 to 4.5 microns wide. On shaking, behaved as the Cuban yeast. Plate III, Fig. 7.

*Sporulation.*—Spores were formed on gypsum blocks in 96 hours at 32° C., the sediment from a 36-hour old culture in beer wort being used; the cells contained from two to three spores, four spores not being observed. Sporulation was infrequent. Plate IV, J.

*Propagation and Physiology.*—As for Cuba.

## MAURITIUS.

*Beer wort, 36 hours old.* Cells round to oval, 6 to 7 microns long by 4.5 to 5 microns wide. Plate I, Fig. 8.

*Agar beer wort plate cultures, 36 hours old.* Colonies as for the Cuban yeast. Plate II, Fig. 10.

*Sediment from beer wort, 10 days old.* Cells oval, granular, generally with one vacuole, 5.5 to 7 microns long by 4 to 5 microns wide; on shaking, the sediment coagulated to a cheesy mass and settled at once to the bottom of the flask. Plate III, Fig. 1.

*Sporulation.*—Spores were very sparingly formed at 32° C., using the sediment from a 36-hour old beer wort fermentation; they formed in 96 hours on gypsum blocks two, three or four spores in cell, three or four being most common. Plate IV, M.

*Propagation and Physiology.*—As for Cuba.

## NATAL NO. 1.

*Beer wort, 36 hours old.* Very large circular to oval cells; from 7.5 to 10.5 microns long by 6.5 to 9.5 microns wide, frequently with a large central vacuole. Plate I, Fig. 4.

*Agar beer wort plate cultures, 36 hours old.* Colonies as for Cuban yeast. Cells oval to circular, smaller than in beer wort, from 5.5 to 8 microns long by 4.5 to 6 microns wide, generally with one vacuole. Plate II, Fig. 2.

*Sediment from beer wort, 10 days old.* Large round to oval, granular cells with usually one large central vacuole from 5.5 to 9.5 microns long and 4.5 to 9 microns wide. Plate III, Fig. 3. On shaking, behaved as the Cuban yeast.

*Sporulation.*—Spores were freely formed in 48 hours at 32° C. on gypsum blocks, using the sediment from a 36-hour old beer wort fermentation; two, three or four spores in one cell. Plate IV, N.

*Propagation and Physiology.*—As for Cuba.

#### NATAL No. 2.

*Beer wort, 36 hours old.* Circular to oval cells, 6 to 7.5 microns long by 5 to 6 microns wide, generally with two vacuoles. Plate I, Fig. 6.

*Agar beer wort plate cultures, 36 hours old.* Colonies as for Cuban yeast. Cells oval, very granular, generally with two vacuoles from 5.5 to 7.5 microns long by 3 to 4.5 microns wide. Plate II, Fig. 1.

*Sediment from beer wort, 10 days old.* Cells oval to round from 5.5 to 9.5 microns long by 4.5 to 9 microns wide. On shaking, behaved as the Cuban yeast. Plate III, Fig. 4.

*Sporulation.*—Spores were formed freely on gypsum blocks in 48 hours at 32° C., two, three or four spores in a cell. Plate IV, N2.

*Propagation and Physiology.*—As for Cuba.

#### PERU.

*Beer wort, 36 hours old.* Elongated cells, sometimes club-shaped, from 7.5 to 12 microns long by 3.5 to 4.5 microns wide. Plate I, Fig. 9.

*Agar beer wort plate culture, 36 hours old.* Colonies as for Cuban yeast, but only up to 1 mm. diameter. Cells elongated and irregular in shape, being often constricted in the middle, and with two to four vacuoles. Plate II, Fig. 3.

*Sediment from beer wort, 10 days old.* Cells extremely granular, regular in outline from 5.5 to 7 microns long by 2.5 to 4.5 microns wide. Plate III, Fig. 5.

*Sporulation.*—Spores were not obtained on gypsum blocks or on carrot at any temperature; they were formed very readily in four days on wort agar plates at the laboratory temperature of 20° C. to 25° C.; four spores were formed in one cell, the outline of which was often irregular. Plate IV, P.

Propagation was by fission, a transverse septum being formed across a median line. Plate II, Fig. 3.

*Physiology.*—As for Cuba.

## TRINIDAD.

*Beer wort, 36 hours old.* Cells oval to circular from 5.5 to 7 microns long by 5 to 6 microns wide. Plate I, Fig. 3.

*Agar beer wort plate cultures.* Colonies as for Cuban yeast. Cells generally oval, very granular, from 4.5 to 7 microns long by 3.5 to 4.5 microns wide. Plate II, Fig. 6.

*Sediment from beer wort, 10 days old.* Cells generally oval with one large central vacuole, granular; from 5.5 to 7 microns long by 4 to 5 microns wide. Plate III, Fig. 6. On shaking, behaved as for Cuba.

*Sporulation.*—Spores were sparingly formed on gypsum blocks at 32° C. in 60 hours; two, three, and four spores in a cell. Plate IV, T.

*Propagation and Physiology.*—As for Cuba.

## SUMMARY.

1. The average content of sugars of twenty-five Hawaiian molasses for the crop of 1908 was 51.68 per cent.
2. Of these sugars, 83 per cent. can be converted by fermentation into alcohol.
3. An unfermentable body, which has the same reducing power on copper solutions as glucose, is present to the extent of 6.13 per cent. of the sugars, or 3.17 per cent. of the molasses.
4. The United States revenue regulations governing molasses distilleries is based on an estimated yield of from 80 to 95 per cent. of proof spirit from the molasses. The yields of Hawaiian molasses vary from 62 to 93 per cent., the average being 77 per cent. A modification of the regulations would be necessary before a molasses distilling enterprise could be profitably installed in these islands.
5. Molasses contains a sufficiency of nutrients for the development and action of yeast.
6. Mineral stimulants give no apparent increase in the yield.
7. The molasses contain no non-sugars which have a deleterious action on the fermentation.
8. Aeration shortens the time of fermentation, without any increase in alcohol yield.
9. Attenuation is not as great in molasses of Hawaii as in those of most countries where molasses is fermented, on account of the smaller quantities of sugars therein.
10. Fermentation under pure culture increased the yield in alcohol 22 per cent. over that when working under the usual factory conditions with adventitious fermentation.

11. The lees or residue from fermentation gives a fertilizer containing potash, nitrogen, and a small quantity of phosphoric acid.

12. Molasses as a source of alcohol and fertilizer has a value of about 8.3 cents per gallon, exclusive of freight and interest.

13. Of the yeasts from various countries where the molasses is fermented, most are budding yeasts of the type *Saccharomyces vordermanni*; that from Peru is, however, a fission yeast.

14. Most of the yeasts worked well in sugar concentrations up to 14.6 grams per 100 cc., the fermented wash containing up to 7.85 per cent. alcohol by volume.

15. A *Monilia* was isolated from the yeast from Natal, which gives an aroma resembling that of the best Jamaica rum.

In conclusion, the writers desire to express their obligations to Mr. L. Lewton-Brain for many valuable suggestions, and to Messrs. A. E. Jordan and F. T. Dillingham for considerable assistance in the analytical work.

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### EXPLANATION OF PLATES.

In the accompanying plates, prepared from camera lucida, drawings by Mr. W. R. Potter, is shown the appearance of the yeasts and other organisms studied.

Plate I, Fig. 1—Java yeast, 36 hours old in beer wort.

Plate I, Fig. 2—The monilia from Natal, 36 hours old in beer wort agar.

Plate I, Fig. 3—Trinidad yeast, 36 hours old in beer wort.

Plate I, Fig. 4—Natal yeast, No. 1, 36 hours old in beer wort.

Plate I, Fig. 5—Demerara yeast, 36 hours old in beer wort.

Plate I, Fig. 6—Natal yeast, No. 2, 36 hours old in beer wort.

Plate I, Fig. 7—Cuba yeast, 36 hours old in beer wort.

Plate I, Fig. 8—Mauritius yeast, 36 hours old in beer wort.

Plate I, Fig. 9—Peru yeast, 36 hours old in beer wort.

Plate II, Fig. 1—Natal yeast, No. 2, agar beer wort plate, 36 hours old.

Plate II, Fig. 2—Natal yeast, No. 1, agar beer wort plate, 36 hours old.

Plate II, Fig. 3—Peru yeast, agar beer wort plate, 36 hours old.

Plate II, Fig. 4—*Monilia javanica*, agar beer wort plate, 36 hours old.

Plate II, Fig. 5—Cuba yeast, agar beer wort plate, 36 hours old.

Plate II, Fig. 6—Trinidad yeast, agar beer wort plate, 36 hours old.

Plate II, Fig. 7—Demerara yeast, agar beer wort plate, 36 hours old.

Plate II, Fig. 8—Java yeast, agar beer wort plate, 36 hours old.

Plate II, Fig. 9—*Monilia javanica*, 36 hours old in beer wort.

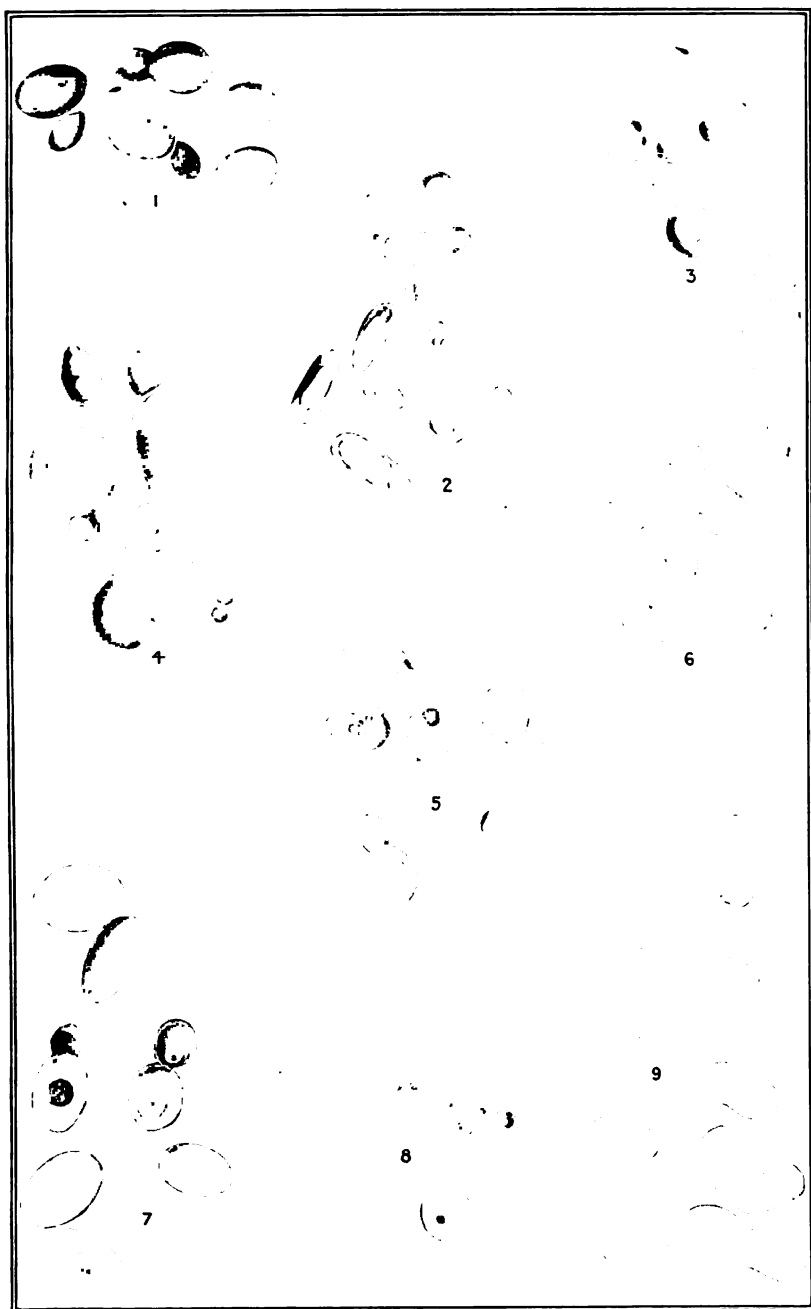
Plate II, Fig. 10—Mauritius yeast, agar beer wort plate, 36 hours old.

Plate II, Fig. 11—The monilia from Natal, 36 hours old in beer wort.

Plate III, Fig. 1—Mauritius yeast, sediment from beer wort, 10 days old.



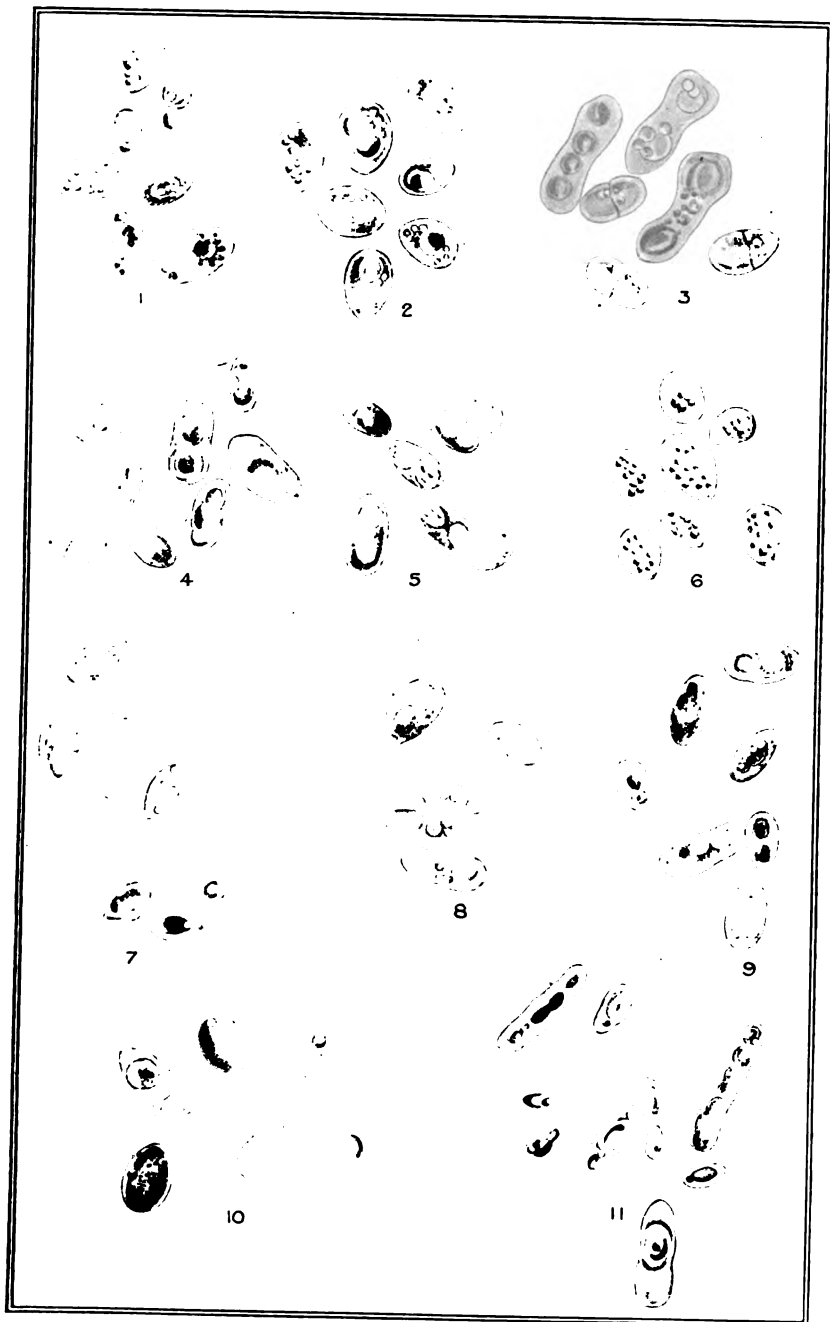
- Plate III, Fig. 2—Cuba yeast, sediment from beer wort, 10 days old.
- Plate III, Fig. 3—Natal yeast, No. 1, sediment from beer wort, 10 days old.
- Plate III, Fig. 4—Natal yeast, No. 2, sediment from beer wort, 10 days old.
- Plate III, Fig. 5—Peru yeast, sediment from beer wort, 10 days old.
- Plate III, Fig. 6—Trinidad yeast, sediment from beer wort, 10 days old.
- Plate III, Fig. 7—Java yeast, sediment from beer wort, 10 days old.
- Plate III, Fig. 8—Demerara yeast, sediment from beer wort, 10 days old.
- Plate IV. C—Sporulation of Cuba yeast.
- Plate IV. D—Sporulation of Demerara yeast.
- Plate IV. J—Sporulation of Java yeast.
- Plate IV. M—Sporulation of Mauritius yeast.
- Plate IV. N—Sporulation of Natal yeast, No. 1.
- Plate IV. N<sub>2</sub>—Sporulation of Natal yeast, No. 2.
- Plate IV. P—Sporulation of Peru yeast, No. 2.
- Plate IV. T—Sporulation of Trinidad yeast, No. 2.



x 640

PLATE I.

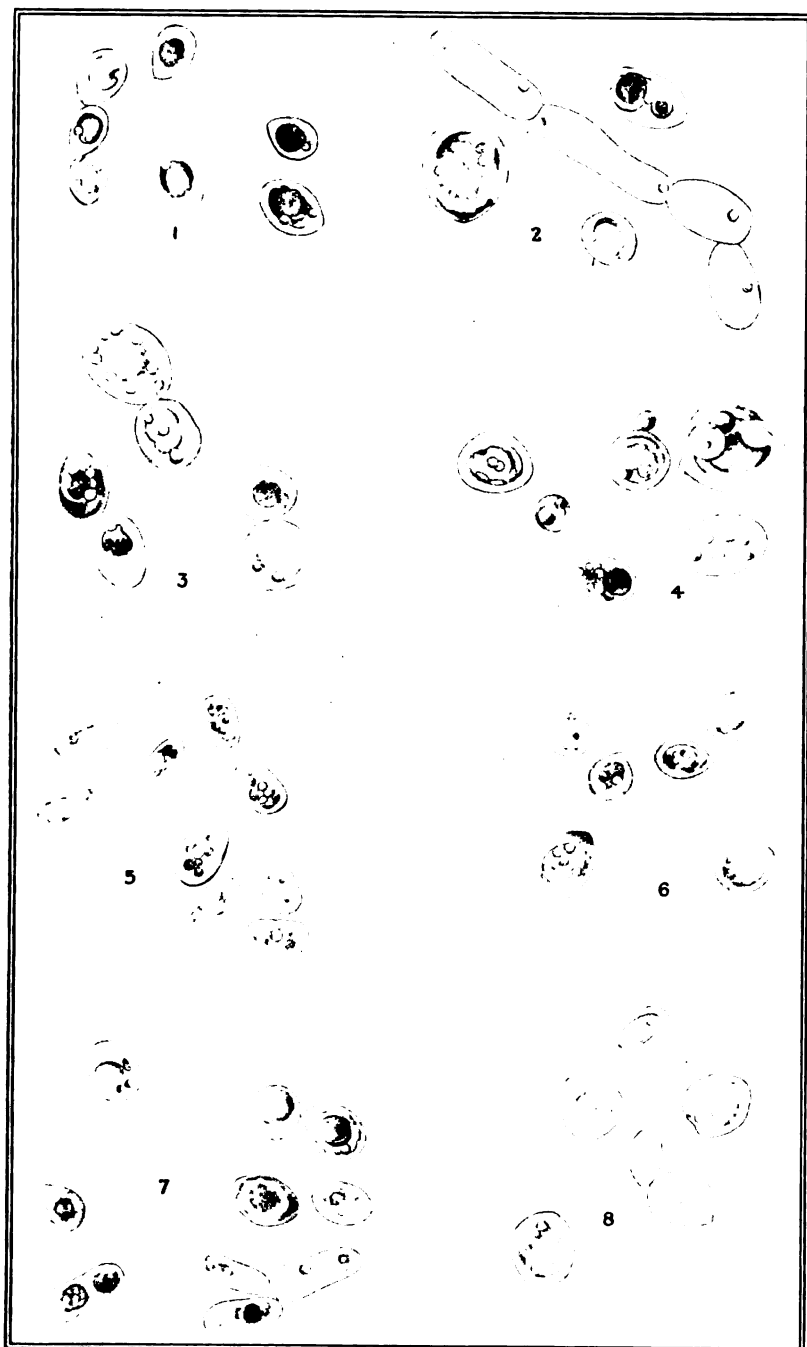




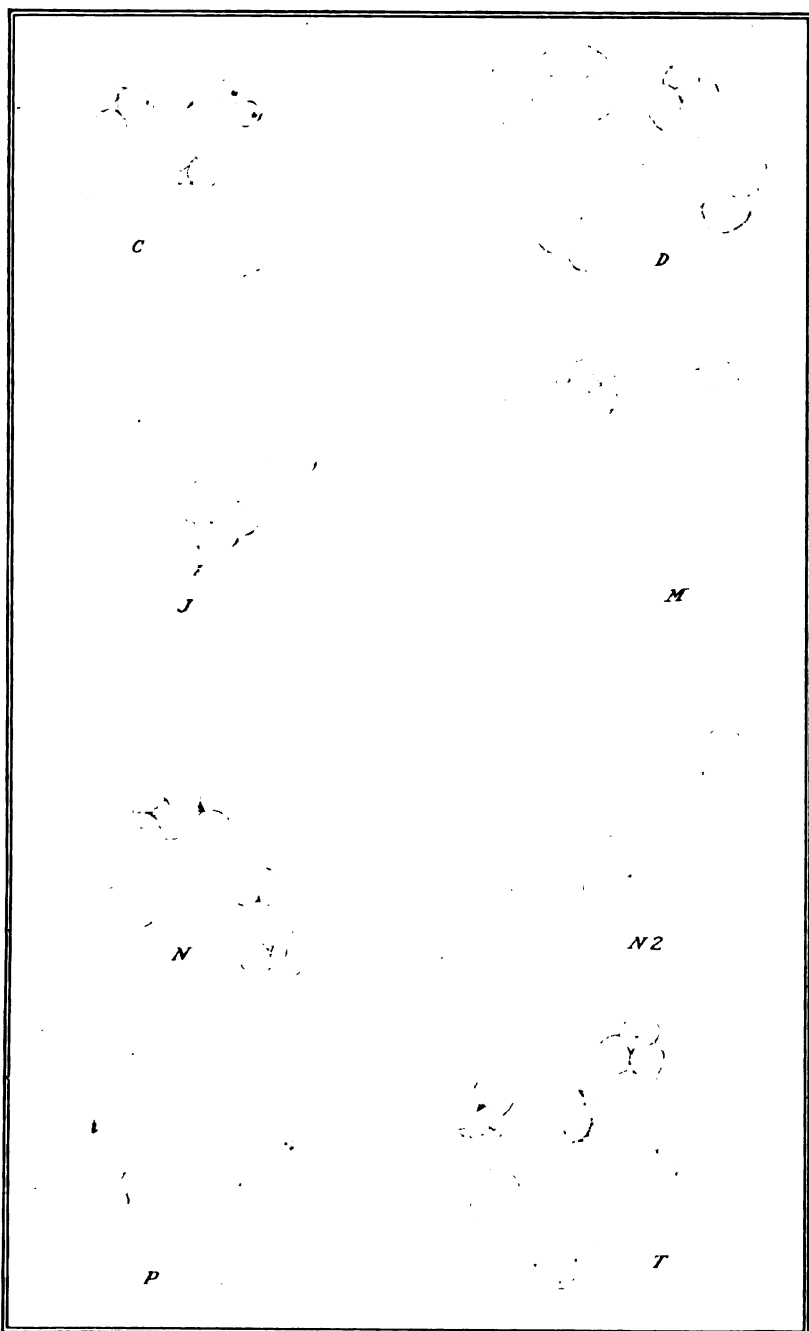
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PLATE II.



















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BULLETIN NO. 29

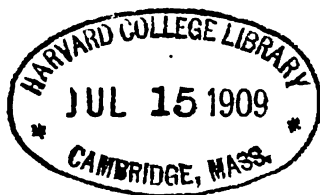
REPORT OF WORK  
OF THE  
**EXPERIMENT STATION**  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION



**The Action of Soluble Fertilizers  
on Cane Soils.**

BY C. F. ECKART

HONOLULU, HAWAII  
1909



## LETTER OF TRANSMITTAL.

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To The Experiment Station Committee of the Hawaiian Sugar  
Planters' Association, Honolulu, T. H.

Dear Sirs:

I herewith, submit for publication as Bulletin No. 29 of the  
Division of Agriculture and Chemistry, an article entitled: The  
Action of Soluble Fertilizers on Cane Soils.

Yours very truly,

C. F. ECKART,

Director, Division of Agriculture & Chemistry.

Honolulu, Hawaii, May 13, 1909.





# The Action of Soluble Fertilizers on Cane Soils.

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BY C. F. ECKART.

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The nature of the experiments under consideration in this article were described at some length in circular No. 6, of the Division of Agriculture and Chemistry when the results from the treatment of plant cane with various combinations of fertilizer salts were presented in connection with substation work then in progress. In this bulletin are presented the data obtained from a crop of plant cane, planted in 1905, and the succeeding ratoons, cut during the present season, in each of the several localities. These experiments, therefore, practically cover a period of four years, and permit a comparison of the effects of fertilizers applied to plant and ratoons.

The object of these experiments was to ascertain the degree of reliance which could be attached to the analysis of soils, in determining fertilizer requirements. To quote from Circular No. 6: "These tests were started with the object of ascertaining the fertilizer requirements of cane grown on different soils, and under different climatic conditions, and of reviewing the data, so obtained, in connection with the composition of the soils as shown by their chemical analyses. It was considered important, owing to the large number of fertilizer recommendations which are continually made by this Experiment Station, and which are based largely upon average weather conditions and analytical results from soil samples, to gauge the reliability of this system in a rigidly practical manner."

The ordinary, so-called "agricultural method" of analysis, in which the amounts of the soil elements soluble in a solution of hydrochloric acid of definite strength (1.115 sp. gr.) are determined, was found unsuitable as affording an index of soil fertility. This was believed to be due to the fact that large quantities of a certain soil element, such as potash, for instance, might go into

solution in dilute hydrochloric acid, and still exist in a very insoluble condition in the soil. In other words, a strong solvent would not indicate the availability to plants of the important nutrients in the soil, but might, on the other hand, give information of some value concerning the total supplies of the essential elements. Accordingly weak organic acids were substituted for hydrochloric acid by many soil chemists, and it was generally believed that a nearer approach to a reliable fertility index was obtained in this way. At this Station the "aspartic acid method" of soil analysis was evolved by W. Maxwell in 1898, who stated, after a detailed investigation: "a one per cent solution of aspartic acid takes out of Hawaiian soils in 24 hours the same amounts of lime, potash and phosphoric acid that are removed during the production of ten crops of cane. Therefore one-tenth of these amounts may be taken as the proportions of lime, potash and phosphoric acid that are available for the immediate crop of cane." (*Lavas and Soils of the Hawaiian Islands*, page 134). While this statement is open to criticism with respect to the actual quantities of plant foods available in a given soil, as indicated by the aspartic acid method of soil analysis, we might expect the method in question to yield information of some value with respect to the relative fertility of soils.

Owing to the enormous sums spent annually in Hawaii in the fertilization of the cane lands, it was deemed advisable by the writer to seek confirmation in the plantation field of the knowledge derived from the laboratory examination of soils by the aspartic acid method.

When we stop to consider the multiplicity of known factors controlling the growth of cane, or any other crop, it becomes evident that the inter-relationship between the many concomitant influences brought to bear on the yields of product makes the subject extremely complex. If we go a step further, and consider that a host of unknown factors involved in crop production still await recognition at the hands of research workers, and that these in turn are climatic, physical, chemical and biological in their nature, the inter-dependence of the many influences involved in soil fertility becomes still more complicated. It should therefore not be a matter of surprise if any method of chemical or physical analysis of soil, no matter how carefully devised, should fall short in yielding the information desired with respect to manurial requirements, although it might prove of some value in indicating, in a general way, the most economical

cultural methods to pursue in the maintenance or improvement of soil fertility.

In dealing with the large amount of data obtained from the substation experiments under consideration in this bulletin, the following plan of presenting the information gained will doubtless prove the most satisfactory. The manurial treatment of the separate plats will first be given, the manner of interpreting the results will be considered, and the apparent effects of the different combinations of fertilizer salts on the several experiment areas will be briefly outlined, together with the relative amounts of lime, nitrogen, and potash and phosphoric acid found in the soil as the result of analysis by the agricultural and aspartic acid methods. A review of the results obtained and the general conclusions to be deduced from the tests will then follow, beginning with page 20, and the more detailed data pertaining to the experiments will appear in the appendix.

#### *Manurial Treatment of Plats.*

The fertilizer mixtures applied to the respective plats contained the following amounts of nitrogen, as sulphate of ammonia; potash, as sulphate of potash; and phosphoric acid as superphosphate; the application of these ingredients being calculated to the rate per acre.

Plat No. 1 Nitrogen, 60 lbs.; Potash 60 lbs.; Phos. Acid, 60 lbs.

"	"	2	"	60	"	"	60	"	"	90	"
"	"	3	"	60	"	"	90	"	"	60	"
"	"	4	"	90	"	"	60	"	"	60	"
"	"	5	"	90	"	"	90	"	"	60	"
"	"	6	"	90	"	"	60	"	"	90	"
"	"	7	"	60	"	"	90	"	"	90	"
"	"	8	"	90	"	"	90	"	"	90	"
"	"	9	"	60	"	"	60	"	"	None	

#### INTERPRETATION OF RESULTS.

Unless results from field tests may be correctly interpreted very misleading conclusions may be reached, thus rendering the experiments worse than useless. In common practice it is usually considered sufficient to lay out a series of plats in a field, one of which is left untreated as a check, or basis for comparison, while the others are treated in various ways. In the large ma-

jority of cases this system, while simple, yields very unreliable data, except when the tests are conducted through a long period of years.

The maximum difference between yields of cane on nine plats in a series where the treatment given the plats was the same, has been observed by the writer to amount to as much as 22 tons. If these plats had, with the exception of one, been treated in different ways, with the object of comparing the effects of different cultural methods, it is quite evident that large differences which were entirely due to variations in the soil, planting material, etc., would have been attributed to certain agricultural practices under investigation.

In laying out the series of fertilizer experiments under consideration, the tests were conducted in duplicate, and each fertilized plat was located directly opposite (and practically adjoining) an unfertilized plat. The average yields of cane on the two corresponding fertilized plats, when compared with the average yields on the two corresponding unfertilized plats, would be expected to afford more reliable data than the usual system previously alluded to. Unfortunately, although differences due to the usual disturbing factors were greatly reduced by the procedure outlined, they persisted sufficiently to make a fair interpretation of results a matter of some complexity. It was found that the difference in yields between adjacent unfertilized plats was often considerable, and since we would expect approximately equivalent differences to exist from the same causes between the untreated plats and the adjacent treated plats; it is at once seen that accurate comparisons based on percentages of gain or loss are precluded. Furthermore, these differences between the yields of adjacent untreated plats were often more than those between two adjacent plats in the fertilized series, so that the relative action of different mixtures of fertilizer salts was in some cases entirely obscured. These points may probably be brought out more clearly by presenting the average results from plant and ratoon cane at Substation A as an example.

AVERAGE YIELDS OF SUGAR FROM PLANT CANE AND RATOONS AT  
SUBSTATION A.

PLAT	Fertilization, Lbs. per Acre.			Sugar, Tons per Acre		Difference in Yields Between Adjacent Fertilized Plats	Difference in Yields Between Adjacent Unfertil- ized Plats
	Nitro- gen	Potash	Phos. Acid	Fertil- ized	Not Fertil.		
1	60	60	60	6.97	4.29	....	....
2	60	60	90	6.48	4.41	.49	.12
3	60	90	60	6.56	4.46	.08	.05
4	90	60	60	8.27	4.53	1.71	.07
5	90	90	60	7.69	4.57	.58	.04
6	90	60	90	7.45	4.05	.24	.52
7	60	90	90	6.81	3.94	.64	.11
8	90	90	90	8.10	4.43	1.29	.49
9	60	60	none	6.72	4.22	1.38	.21

At first glance it will appear as if the unfertilized plats are sufficiently uniform to permit accurate comparisons. It will be noticed, however, that there are two discrepancies which are quite considerable; adjacent plats 5 and 6 show a difference of .52 ton, and adjacent plats 7 and 8 show a difference of .49 ton. Now since adjacent untreated plats can in this area vary as much as .52 ton of sugar, it is possible that equivalent differences, due to uncontrollable causes, may exist between treated plats and the corresponding adjacent untreated plats with which they are compared. For instance, it is possible that plat No. 3, in the fertilized series, may without fertilizer have been capable of producing  $4.46 + .52 = 4.98$ , or  $4.46 - .52 = 3.94$ , tons sugar. In the former case, the gain from fertilization would actually be 31.7 per cent, and in the latter case, 66.5 per cent. Although the indicated gain in this case is 47 per cent, it can only be put down as a rough approximation. The indicated percentages of gain as given in the tabulated data in the appendix of this bulletin must therefore be only applied in a very general way. Instead of showing actual gains they indicate the general trend of results which may be expected to follow the applications of certain salts in varying quantities on a given soil.

Since we would not expect the treated plats to vary more from soil differences, etc., than those which had been left untreated, it is possible to acquire considerable definite information concerning the action of different fertilizer mixtures in the following

manner. In comparing the *differences* between yields on the fertilized plats if we accept only those for our purposes which are greater than the maximum difference between the yields of plats on the unfertilized area, we can feel practically certain that the variations observed are due to differences in treatment to an extent at least equal to the difference in yields of the fertilized plats compared, *minus* the maximum difference found on the untreated area. To make this clear, we take as an example plats Nos. 2 and 4, of Substation A. Referring to the table on page 9, it will be noted that plat No. 2 yielded 6.48 tons sugar, while plat No. 4 gave 8.27 tons. For reasons already explained we cannot consider that the difference in yields between these two plats, namely, 1.79 tons, may be attributed to the difference in fertilization, although we may safely infer that the difference in fertilization affected the yield at least to the extent of  $1.79 - .52 = 1.27$  tons, in favor of the application of 90 lbs. nitrogen, 60 lbs. potash, and 60 lbs. phosphoric acid, when this mixture was compared with 60 lbs. nitrogen, 60 lbs. potash and 90 lbs. phosphoric acid. The extent to which this method will allow us to compare the effects of different fertilizers at Substation A, for instance, is shown in the following table:

DIFFERENCES IN YIELDS BETWEEN FERTILIZED PLATS AT SUBSTATION A.

Plat	Yields, Tons Avail- able Sugar	2	3	4	5	6	7	8	9
1	6.97	.49	.41	1.30*	.72*	.48	.16	1.13*	.25
2	6.48	...	.08	1.79*	1.21*	.97*	.33	1.62*	.24
3	6.56	...	...	1.71*	1.13*	.89*	.25	1.54*	.16
4	8.27	...	...	....	.58*	.82*	1.46*	.17	1.55*
5	7.69	...	...	....	....	.24	.88*	.41	.97*
6	7.45	...	...	....	....	...	.64*	.65*	.73*
7	6.81	...	...	....	....	...	....	1.29*	.09
8	8.10	...	...	....	....	...	....	....	1.38*
9	6.72	...	...	....	....	...	....	....	....

The yields of sugar on plats 1 to 9 are given in the second column. In the following columns are given the differences in yields between the different plats. For example, the difference in yields between plat No. 4 and plat No. 7 will be found by following a line from plat 4, in the first column, till it meets the

column headed "7;" in this case the figure obtained is 1.46. The figures marked with an asterisk represent differences which exceed the maximum difference between the untreated plats, and from them we may reasonably conclude that changing the fertilization from that represented in column 1 below, to that given respectively opposite in column 2, a distinct gain is effected.

1			2		
Nitrogen	Potash	Phos Acid	Nitrogen	Potash	Phos Acid
60	60	60	90	60	60
60	60	60	90	90	60
60	60	60	90	90	90
60	60	90	90	60	60
60	60	90	90	90	60
60	60	90	90	60	90
60	60	90	90	90	90
60	90	60	90	60	60
60	90	60	90	90	60
60	90	60	90	60	90
60	90	60	90	90	90
90	90	60	90	60	60
90	60	90	90	60	60
60	90	90	90	60	60
60	60	..	90	60	60
60	90	90	90	90	60
90	90	60	90	90	90
60	90	90	90	60	90
90	60	90	90	90	90
60	90	90	90	90	90
60	60	..	90	90	90

In this particular case, the relative great importance of nitrogen in fertilizing mixtures is very forcibly brought out. It is furthermore shown that with nitrogen at 90 lbs., separately increasing either the potash or phosphoric acid to 90 lbs., diminishes the efficiency of the mixture. On page 49, where the apparent percentages of gain in yields are given for the different mixtures at Substation A, it will be found that 90 lbs. nitrogen, 60 lbs. potash, and 90 lbs. phosphoric acid, show an increased yield over the unfertilized area of 83.9 per cent, while 90 lbs. nitrogen, 60



lbs. potash, and 60 lbs. phosphoric acid, give a gain of 82.5 per cent. The results given above, however, indicate that this was due to an inconsistency of the nature already described, and that the extra phosphoric acid added to the mixture actually had a certain depressing effect. As to the economy of applying a mixture of 90 lbs. nitrogen, 60 lbs. potash, and 60 lbs. phosphoric acid, at this substation, we may gain satisfactory information by again consulting the table on page 40. The indicated average gain from all the fertilizer mixtures will be found to be 67.1 per cent, and this figure must be very close to the actual average gain. Now since the mixture of 90 lbs. nitrogen, 60 lbs. potash and 60 lbs. phosphoric acid, has shown greater efficiency than all of the others (with the possible exception of that applied to Plat No. 8), we can take it for granted that the gain in sugar following its use will be considerably greater than 67 per cent, and that it may approximate the apparent per centage, 82.5.

While the other substations do not yield as many definite conclusions, owing to very wide differences between the untreated plats, still, by the same method of reasoning outlined, information of value may be obtained.

The action of the various fertilizer mixtures will now be considered with respect to the soil of the several substations.

## SUBSTATION A.

### *Soil Elements.*

**Potash.** The total potash in this soil is lower than the average for the islands, and the soluble potash is considerably higher. While in the average Hawaiian soil 7 per cent of the potash is soluble in an one per cent solution of aspartic acid, in the soil of Substation A 13.3 per cent is soluble.

**Phosphoric Acid.** The total phosphoric acid is lower than the average, and the soluble phosphoric acid is higher. Of the total phosphoric acid, 1.1 per cent is soluble in the aspartic acid solution, as compared with 0.55 per cent in the average soil.

**Nitrogen.** The soil of this substation contained one-half as much nitrogen as the average island soil.

**Lime.** The total lime is somewhat higher than the average, and the aspartic acid soluble lime is somewhat lower. While the percentage of total lime in the average soil which is soluble in aspartic acid is 24.4, in the soil under consideration it is 15.6 per cent.

**Reaction of Soil.** The reaction of this soil is neutral.

*Effect of Different Fertilizer Mixtures.*

The great relative importance of nitrogen in the fertilization of Substation A has already been referred to. It was further shown that with a complete mixture containing 90 lbs. nitrogen, separately increasing either the potash or phosphoric acid from 60 to 90 lbs. lowered the efficiency of the fertilizer. To ascertain in a general way the relative action of nitrogen, potash and phosphoric acid on this soil, when these elements were applied in mixtures, we can compare the average yields of plats receiving complete mixtures containing 60 lbs. of each element in turn, with those from fertilizers in which the special element under consideration was raised to 90 lbs. For example, the mixtures containing 60 lbs. of nitrogen were:

	Nitrogen. Lbs.	Potash. Lbs.	Phos. Acid. Lbs.
(Plat 1).....	60	60	60
(Plat 2).....	60	60	90
(Plat 3).....	60	90	60
(Plat 7).....	60	90	90

The other mixtures which contained amounts of potash and phosphoric acid corresponding to those given above, but in which the nitrogen was increased to 90 lbs., were:

	Nitrogen. Lbs.	Potash. Lbs.	Phos. Acid. Lbs.
(Plat 4).....	90	60	60
(Plat 6).....	90	60	90
(Plat 5).....	90	90	60
(Plat 8).....	90	90	90

A comparison of the average yields from plats Nos. 1, 2, 3 and 7 with those from plats Nos. 4, 5, 6 and 8 will indicate the general effect of increasing the nitrogen in these mixtures. By making comparisons with the potash and phosphoric acid in the same way, we can gain some knowledge as to the relative importance of the separate elements when applied in mixtures to the soil in question. The following table allows a comparison of this kind.

AVERAGE YIELDS OF PLATS RECEIVING COMPLETE MIXTURES.  
TONS OF AVAILABLE SUGAR PER ACRE.

Mixtures Containing	Plant Cane	Ratoons	Average of Plant and Ratoons
Nitrogen, 60 lbs. ....	6.77	6.63	6.70
Potash, 60 lbs. ....	7.32	7.27	7.29
Phos. Acid, 60 lbs. ....	7.27	7.47	7.37
Nitrogen, 90 lbs. ....	7.68	8.08	7.88
Potash, 90 lbs. ....	7.13	7.45	7.29
Phos. Acid, 90 lbs. ....	7.18	7.25	7.21
Untreated Cane. ....	4.87	3.78	4.32

It will be noted that the average yield from the mixtures containing 60 lbs. nitrogen was lower than those from the mixtures containing 60 lbs. potash, or the same amount of phosphoric acid. The 60 lbs. phosphoric acid mixtures gave the highest yield. When 90 lbs. of nitrogen were applied, the yield exceeded those from the 90 lbs. potash and 90 lbs. phosphoric acid mixtures. The 90 lbs. phosphoric acid mixture in this case gives the lowest yield. In other words, the order of yields becomes directly reversed, and this occurs on all of the substations under consideration.

The effect of increasing the nitrogen from 60 to 90 lbs. is very marked, both with plant and ratoon cane. Increases of potash and phosphoric acid show a depressing action with respect to the plant cane, and this is more distinct with potash than with phosphoric acid. In the case of ratoons the increase in potash apparently caused a small gain, while the phosphoric acid showed the same depressive action as with plant cane.

The average results from plant cane and ratoons would indicate the following apparent order of importance of the several elements:

1. nitrogen
2. potash
3. phosphoric acid.

The most suitable mixture was found to be that containing 90 lbs. nitrogen, 60 lbs. potash, and 60 lbs. phosphoric acid.

The average gain in available sugar from fertilizing the plant cane was approximately 46 per cent, and the ratoons, 93 per cent. The approximate average gain from fertilizing plant and ratoon cane was 67 per cent.\*

## SUBSTATION B.

### *Soil Elements.*

**Potash.** The total and likewise the soluble potash in the soil of Substation B are lower than the average for the islands. While in the average Hawaiian soil 7 per cent of the potash is soluble in the aspartic acid solution, in this particular soil 4.5 per cent is soluble.

**Phosphoric Acid.** The total phosphoric acid is twice as great in quantity, as compared with the average soil, and the percentage of soluble phosphoric acid is slightly lower. Of the total phosphoric acid 0.19 per cent is soluble in aspartic acid, as compared with 0.55 per cent for the islands.

**Nitrogen.** This soil contains nearly three times as much nitrogen as the average soil.

**Lime.** The total lime is lower than the average, and the aspartic acid soluble lime is higher. While the percentage of the total lime in the average soil which is soluble in the aspartic acid solution is 24.4, in the Substation B soil it is 45.1 per cent.

**Reaction.** The reaction of this substation soil is acid.

### *Effect of Different Fertilizer Mixtures.*

The unlimed acid soil of Substation B did not respond to fertilization with these soluble salts in the case of plant cane, except apparently in a few instances. Furthermore, the wide discrepancies which existed in the yields between different untreated plats do not allow definite conclusions to be reached with respect to the more efficient formulas in the case of plant cane. With respect to plant and ratoons there is no distinct evidence that any of the mixtures applied was more economically effective than that containing 60 lbs. nitrogen, 60 lbs. potash, and 60 lbs. phosphoric acid. Following the line of reasoning outlined on page 10, it may be stated with some assurance that the formulas given in column 1 below were less efficient for the ratoons than those given respectively opposite to them in column 2.

\* Tables showing the apparent percentages of gain following the application of the different mixtures will be found in the appendix. The percentages there given, however, cannot form a definite basis for comparison, and must be considered only in a very general way, for reasons already explained.

1			2		
Nitrogen	Potash	Phos. Acid	Nitrogen	Potash	Phos. Acid
60	90	60	60	60	60
60	90	90	60	60	60
60	60	..	60	60	60
60	90	60	90	90	60
60	90	60	90	60	90
60	90	60	90	90	90
60	90	90	90	90	60
60	60	..	90	90	60
60	60	..	90	60	90
60	90	90	90	90	90
60	60	..	90	90	90

A general comparison of the effects of the different elements, when applied in complete mixtures to the soil of Substation B, furnishes the following data with respect to their probable relative importance:

AVERAGE YIELDS OF PLATS RECEIVING COMPLETE MIXTURES.  
TONS OF AVAILABLE SUGAR PER ACRE.

Mixtures Containing	Plant Cane	Ratoons	Average Plant and Ratoons
Nitrogen, 60 lbs.....	6.28	4.12	5.20
Potash, 60 lbs.....	6.38	4.51	5.44
Phos. Acid, 60 lbs.....	6.53	4.41	5.47
Nitrogen, 90 lbs.....	6.72	4.62	5.67
Potash, 90 lbs.....	6.62	4.23	5.42
Phos. Acid, 90 lbs.....	6.47	4.33	5.40
Untreated Cane.....	6.58	3.40	4.97

The figures representing the average yields of plant and ratoon cane indicate that increases in potash and phosphoric acid from 60 to 90 lbs. have an apparent depressive tendency. The efficiency of the mixtures in general was seemingly increased by extra amounts of nitrogen, and the apparent relative importance of the several elements in the fertilization of the cane at Substation B would appear to be as follows:

1. nitrogen
2. potash
3. phosphoric acid.

An average loss followed the fertilization of the plant cane, amounting to approximately one per cent, while the ratoons showed an approximate gain of 26 per cent.

### SUBSTATIONS C. AND D.\*

#### *Soil Elements.*

**Potash.** The total potash in the soil of these two substations is slightly higher than the average for the islands, and the soluble potash is very much lower. Of the total potash only 2.75 per cent is soluble in an one per cent solution of aspartic acid.

**Phosphoric Acid.** The total phosphoric acid is over three times that of the average island soil. The solubility of this element, however, is strikingly low, 0.035 per cent of the total quantity being soluble in the aspartic acid solution.

**Nitrogen.** This soil is higher in nitrogen than the average Hawaiian soil.

**Lime.** The total lime content is low, and the soluble lime very low. The latter represents 23.6 per cent of the former.

**Reaction.** The reaction of this soil is acid.

#### *Effect of Different Fertilizer Mixtures.*

**Substation C, Irrigated.** The data obtained from the tests of this irrigated substation show that the mixtures given in column 1, below, were less efficient in increasing the output of sugar than those given respectively opposite in column 2.

1			2		
Nitrogen	Potash	Phos. Acid	Nitrogen	Potash	Phos. Acid
60	60	60	90	90	60
60	60	60	90	60	90
60	90	60	60	60	90
60	60	90	90	90	60
60	60	90	90	60	90
60	90	60	90	60	60
60	90	60	90	90	60
60	90	60	90	60	90
60	90	60	60	90	90
60	90	60	90	90	90
60	90	90	90	90	60
90	90	90	90	90	60
60	60	..	90	90	60
60	90	90	90	60	90
60	60	..	90	60	90

\* These two substations were immediately adjacent, C being irrigated and D unirrigated.

A further idea concerning the apparent relative importance of the the several elements in the mixtures may be obtained from the following average figures:

AVERAGE YIELDS OF PLATS RECEIVING COMPLETE MIXTURES.  
TONS OF AVAILABLE SUGAR PER ACRE.

Mixtures Containing	Plant Cane	Ratoons	Average of Plant and Ratoons
Nitrogen, 60 lbs.....	5.72	3.41	4.56
Potash, 60 lbs.....	6.22	3.99	5.11
Phos. Acid, 60 lbs....	5.92	3.97	4.95
Nitrogen, 90 lbs.....	6.32	4.69	5.50
Potash, 90 lbs.....	5.81	4.10	4.95
Phos. Acid, 90 lbs.....	6.11	4.12	5.11
Untreated Cane.....	4.10	2.52	3.31

As in the case of Substation A, we find that nitrogen is the element of greatest relative importance in fertilization. On separately raising the quantity of phosphoric acid or potash from 60 to 90 lbs. in mixtures, a certain small increase in yields was apparently effected in the case of ratoons, while with plant cane, increases in potash showed a distinct depressive tendency. The average results from plant and ratoons show the following apparent relative order of importance of the several elements:

1. nitrogen
2. phosphoric acid
3. potash.

It is indicated that the most suitable mixture in the Substation C series of tests was that containing 90 lbs. nitrogen, 60 lbs. potash, and 60 lbs. phosphoric acid.

The average approximate gain in available sugar from fertilizing the plant cane was 44.6 per cent; the gain with ratoons was approximately 61.1 per cent. The general average gain from plant and ratoons was 50.7 per cent.

Substation D, Unirrigated. The soil of this substation was identical to that of Substation C, and the treatment given the plats was the same.

While the indicated relative order of importance of the several elements in the fertilizer mixtures was the same, increases in nitrogen were less effective, and increases in phosphoric acid were more effective in the case where the cane received the smaller amount of water. The discrepancies in the yields of sugar on the untreated plats were more pronounced with respect to Substation D than with Substation C, and only a few definite conclusions are permitted with reference to the relative efficiency of separate formulae, and these apply to ratoons. The formulae given in column 1 were less effective than those respectively opposite in column 2.

1			2		
Nitrogen	Potash	Phos. Acid	Nitrogen	Potash	Phos. Acid
60	60	90	90	60	90
60	90	60	90	90	60
60	90	60	90	60	90
90	60	60	90	60	90
60	60	..	90	60	90

A general idea concerning the apparent relative importance of the several elements is afforded by the following average figures:

AVERAGE YIELDS OF PLATS RECEIVING COMPLETE MIXTURES.  
TONS OF AVAILABLE SUGAR PER ACRE.

Mixtures Containing	Plant Cane	Ratoons	Average of Plant and Ratoons
Nitrogen, 60 lbs.....	5.52	2.73	4.12
Potash, 60 lbs.....	5.88	3.12	4.50
Phos. Acid, 60 lbs.....	5.69	2.91	4.30
Nitrogen, 90 lbs.....	6.18	3.45	4.81
Potash, 90 lbs.....	5.85	3.08	4.46
Phos. Acid, 90 lbs.....	6.04	3.26	4.65
Untreated Cane.....	4.03	2.35	3.18



The tables in the appendix give the largest percentage of gain for this substation as being due to a mixture of 60 lbs. nitrogen, 90 lbs. potash, and 90 lbs. phosphoric acid. This apparently indicated gain is, in view of the other data obtained, obviously incorrect, and the discrepancy may be attributed to the fact that the untreated plat with which fertilized plat No. 7 was compared, gave the lowest yield of sugar of all the untreated plats, thus rendering the percentage of gain abnormally high. This is an excellent illustration of how misleading such results can be when interpreted with insufficient care and reservation.

The most efficient fertilizer for this unirrigated soil, of the soluble mixtures used, was in all probability that containing 90 lbs. nitrogen, 60 lbs. potash and 90 lbs. phosphoric acid. Naturally, this does not mean that these actual weights of the elements would be the most economical to employ, but it indicates that best results may be expected, in practice, when the proportions used are somewhat the same, and nitrogen and phosphoric acid are applied in larger quantities than the potash.

The average approximate gain in available sugar from fertilizing the plant cane was 45.6 per cent; with ratoons, the gain fell to 29.7 per cent. The average approximate gain for plant and ratoons was 39.9 per cent.

## REVIEW OF DATA.

### *Relative Effect of Fertilizer on Plant and Ratoon Cane.*

With the exception of Substation D a marked difference is manifested between the approximate percentage of gain following the fertilization of plant and ratoons, as is shown by the following figures.

GAIN FROM FERTILIZATION. COMPARISON OF PLANT AND RATOONS.  
PERCENT.

		Plant Cane	Ratoons	Average Gain
Substation	A.....	46.8	93.3	67.1
"	B.....	1.4	26.2	5.2
"	C.....	44.6	61.1	50.7
"	D.....	45.6	29.7	39.9

In making a comparison of this kind, it is, of course, necessary to bear in mind that two different crops of cane are considered and that these crops, while receiving the same manurial treatment, were subjected to different climatic influences. In the case of Substation C for instance, the cane, both as plant and ratoons, was not allowed to suffer from want of water, while it is possible that with Substation D the plant cane may have been more favored than the ratoons with respect to the distribution of rain during its period of growth; this, among other differences in connection with relative temperature, humidity, cloudiness, etc., could materially influence the growth of cane and indirectly the effect of fertilizers.

A comparison of the data yielded by the fertilized and unfertilized plats of Substations C and D, points rather strongly, however, to the fact that the continued use of these special soluble salts on unlimed land acted more deleteriously on the ratoons of the unirrigated area than on that which was irrigated. The irrigation water at Substation C not having been measured (as was originally planned), it would not be well to attach too much importance to special differences observed between these two substations with respect to the action of fertilizers.

The probable explanation of the fact that the ratoons in three cases out of four showed a larger percentage of gain from fertilization than was the case with plant cane, is that the unfertilized soil of the check experiments was relatively so much poorer in plant food when under ratoons than when under plant cane. It is more reasonable to suppose that the soil in one case contained less of the cane nutrients than in the other, and hence responded better to manurial treatment than to infer that the ratoons demanded a larger supply of these nutrients than the plant cane per unit of growth. Again, through the thorough preparation of the soil for planting, larger quantities of the essential cane nutrients are rendered available for the plant cane than are afforded through the ordinary tillage operations for ratoons. That a difference in root development between plant cane and ratoons, owing to a difference in the compactness of the soil makes the second crop more appreciative of fertilizer applications than the first, is within certain limits, also probable. The relative compactness of the soil will influence the degree of root ramification and consequently limit to some extent the supplies of plant food with which the root hairs come in contact. Unless the compacting of the soil has progressed to a point in which diminished aeration and drainage, etc., become predominant restraining factors, and

the relative inability of the plant to feed becomes a more important consideration than the quantity of plant food available, in increasing the supplies of the latter might, from this cause, produce a more salutary effect with ratoons than with plant cane.

*Difference in Gains due to Difference in Mixtures.*

One of the most striking points observed in connection with the fertilizer experiments under consideration in this bulletin, is the large difference in yields often produced by variations in the mixtures of fertilizer salts applied.

While, as was previously stated, certain differences in the plots themselves have no doubt influenced the yields of cane in these tests, as in the case of all field experiments, the fact remains that a careful review of the data at hand furnishes evidence that the relative proportions of the several salts employed in the different mixtures often have a marked effect on the yields of product. Furthermore, it is indicated that this effect cannot be entirely attributed to the relative direct demands of the cane for the special ingredients in the several mixtures at the respective substations.

It has long been recognized that certain salts, like sulphate of ammonia, can create acidity in soils, and that nitrate of soda and sulphate of potash can deflocculate clays, and so on, thus producing injury to growing crops; and likewise, that innumerable chemical reactions may follow the application of manures rendering various elements available, but it is quite probable that these physical and chemical changes are not, *per se*, the direct causes of the variations in yields under consideration.

In Bulletin 15, of this Station, the writer showed that by the associated application of fertilizer elements, such as nitrogen, potash, and phosphoric acid, in various combinations, the gains from a combination were in some cases materially different from the aggregate gains following the separate applications of the component salts. For instance, in a test covering six years with Rose Bamboo cane, the following elements, applied alone at the rate of 100 lbs. per acre, gave an average gain per crop as follows:

Nitrogen.....	3,576 lbs. Sugar
Potash.....	2,492 lbs. Sugar
Phosphoric acid.....	1,792 lbs. Sugar

The aggregate gain in this instance was 7,860 lbs. sugar. When, however, the same quantities of the same elements were applied in a mixture, the resulting gain was 5,116 lbs., or 2,744

lbs. less than the calculated aggregate gain already referred to. It was also noted in Bulletin No. 15, that "the fact that the application of one particular element gives negative results with respect to fertilization, does not warrant the assumption that the element in question may, with profit, be omitted as a component part of mixed fertilizers. Applied with another element, the gains may be considerably greater than could be obtained with the latter element alone." In an eight year test with four successive crops of Lahaina cane, for instance, it was found that potash, applied in the form of sulphate of potash, gave apparently no results; when applied with nitrogen, however, a very large gain resulted, which was due to the associated application of the two elements. This may be shown as follows:

Fertilizer Applied	Tons Sugar	Gain Percent
No Fertilizer.....	9.48	....
Nitrogen .....	11.38	20.0
Potash .....	9.57	0.9
Nitrogen+Potash .....	13.92	46.8

In Bulletin No. 9 of this Division, a still more striking example is afforded of the effects produced by the association of elements. In this case fertilizer experiments with two varieties of cane (harvested in 1903) gave the following results which bear particularly on the point under consideration:

YIELDS OF SUGAR PER ACRE. LBS.

Treatment	Rose Bamboo	Lahaina
No Fertilizer.....	17,993	17,525
Phosphoric Acid.....	15,267	15,392
Potash .....	17,158	14,357
Phosphoric Acid+Potash...	21,128	20,555

PERCENTAGE OF GAIN OR LOSS FROM FERTILIZATION.

Element Applied	Rose Bamboo	Lahaina
Phosphoric Acid.....	-15.2	-12.2
Potash .....	-4.6	-18.1
Phosphoric Acid and Potash	+17.4	+14.7

In this series of tests the phosphoric acid and potash were applied at the rate of 100 lbs. each per acre in the form of double superphosphate and sulphate of potash, respectively.

It was shown by the above experiments that separate applications of the different manurial salts to a field cannot be relied upon to indicate the fertilizer requirements. In planning the present series of substation fertilizer tests, it was therefore considered essential to apply the elements together and vary the proportions in different ways.

A very detailed investigation by the Bureau of Soils of the United States Department of Agriculture into the relative efficiency of salts when used alone and in combination, is reported by F. D. Gardner in Bulletin No. 48 (March 21, 1908), of that Bureau. Altogether 220 samples of soil, taken from twenty-three States, were tested by the "paraffin-pot method," and, in a general way, the data obtained conform with the results obtained by this Experiment Station with actual field tests with sugar cane. Gardner states: "The variation in the efficiency of a fertilizer ingredient as used separately and in several combinations bears no consistent relation to the efficiency of the ingredients with which it is associated or to the efficiency of the combination as a whole. If nitrate of soda produces an increase in growth which equals or exceeds that produced when it is associated with potash and phosphate, \* \* \* \* we would theoretically expect little or no effect from either potash or phosphate when used alone on the same soils. Contrary to this theory, however, we find that, with an occasional exception, both potash and phosphate are markedly efficient on these soils. On the other hand, if nitrate of soda produces little or no increase as compared with a fair to good increase obtained when it is combined with potash and phosphate, \* \* \* \* we should expect to obtain fair to good results from potash or phosphate when used alone on the same soils. But what do we find? Usually little or no effect from potash, and a negative effect from the phosphate."

*Cause of Relationship Between Plant Growth and Proportions of Fertilizer Salts in Mixtures.*

In the opinion of the writer, the cause for the apparent relationship which exists between the yields of cane and the relative proportions of component salts in fertilizer mixtures may probably be explained in the following manner.

The plant nutrient which influences in largest measure the growth of cane is nitrogen. Other elements such as potash, phosphoric acid, lime, etc., are usually present in soils in sufficient quantities to supply regularly the needs of a moderate crop, and, furthermore, during the growth of this crop the soil water contains a practically constant proportion of these elements in any one given soil. With nitrogen, on the other hand, the case is radically different, owing to the fact that the amounts present in the soil water as nitrates must be continually influenced by several factors, namely:

a. The relative and combined activities of certain soil bacteria as influenced by conditions of aeration, moisture, etc.

b. The fugitive nature of nitrates and the readiness with which they may be leached from a soil by rains or irrigation.

c. The amounts of the element used by the plants.

The solubility of some of the mineral elements is also affected to some extent by bacterial activity in the production of carbon dioxide from the oxidation of organic matter, and in other ways, but this varying action cannot alter the composition of the soil water to any appreciable extent.

We are all familiar with the fact that the "yellowing off" of the cane in the early spring on many of the fields of Hawaii is, in the great majority of cases, due to a lack of available nitrogen in the soil. Notwithstanding a large content of organic matter, the lower temperatures prevailing during the winter months, coupled with the almost incessant rains, which keep the soils continually saturated, check the activity of the nitrifying organisms and deplete any surplus supplies of nitrates which might have been formed in the autumn. Consequently, small dressings of nitrate in such cases have beneficial effects and the cane rapidly assumes a normal green color. The amount of available nitrogen in any given soil is therefore more variable than is the case with the other plant nutrients, since it is more readily influenced by a number of inter-dependent factors. It is therefore evident that any treatment given a soil, which influences the activity of the micro-organisms responsible for the formation of nitrates, will in one way or another influence the crop growth. This leads us to a consideration of the bacterial flora of soils and the effects which certain agents have upon the activities of these organisms.

The fact that carbon bisulphide, when applied to a soil, resulted in a materially increased growth of plants, was definitely established by Oberlin and Girard in 1894. The action of this

disinfectant on soils naturally received close attention at the hands of investigators, and the conclusions drawn from these observations are put forward by Voorhees and Lipman in their admirable "Review of Investigations in Soil Bacteriology" (Bulletin 194, Office of Experiment Stations, U. S. Department of Agriculture) as follows: "Most of the investigators who have examined this problem, and particularly Hiltner and Störmer, and Kruger and Heinze, ascribe the action of carbon bisulphide to its influence on the bacteria in the soil. Indeed, the evidence supplied by these investigators is quite convincing, and it sheds not a little light on the general question of soil fertility as affected by micro-organic life. Hiltner and Störmer found that under normal conditions there is a certain equilibrium established among the various groups of soil bacteria, and that the organisms capable of growing on meat-extract gelatin are composed of *Streptothrix* species 20 per cent, gelatin-liquifying species 75 per cent, and non-liquifying species 5 per cent. But when carbon bisulphide is applied to the soil, its bacterial inhabitants are injured, though not completely destroyed, the injury varying with the changing conditions of temperature, moisture, and amount of carbon bisulphide applied, as well as the duration of its action. Not all of the bacterial species are depressed in their development to an equal extent, the injury being most pronounced in the *Streptothrix* species, and least pronounced in the gelatin-liquifying species. The depressing action of carbon bisulphide disappears after a shorter or longer interval, and is followed by a very rapid multiplication of the micro-organisms in the soil. The equilibrium having been destroyed, however, the new development follows along different channels, and there occurs not only an enormous increase in the total number of soil bacteria, but also an abnormal predominance of certain species. The new conditions thus established for a time favor a more ready utilization of the stores of soil nitrogen and likewise the fixation of atmospheric nitrogen by certain bacterial species. It is for this reason that the application of carbon bisulphide is followed after a time by a very decided increase in crop yields as compared with the corresponding yields from soils not treated. Increased harvests under such conditions have been observed by Oberlin, Kruger and Heinze, Koch, Moritz and Scherpe, Caron, Behrens, Girard and others."

When it is considered that countless millions of bacteria are at work in every soil, breaking down the organic matter and converting the nitrogen through separate processes into a form

available for plants, and, furthermore, that these separate and supplementary processes are carried on by distinct species of organisms, which require different conditions for their maximum development and activity, the question of this bacterial equilibrium in a given soil is apparently a matter of importance. If one kind of bacterium is in the ascendancy, and is of such a character that it does not produce ammonification or nitrification or fix free atmospheric nitrogen or carry on other functions of benefit to the plant, it may crowd out or materially reduce in numbers the beneficial micro-organisms which are struggling for existence. Again, since the action of the several species which are concerned in the ultimate formation of nitrates is largely supplementary, one kind attacking the organic matter to form ammonium compounds, another oxidizing the ammonia to nitrites, and another oxidizing the nitrites to nitrates, it is possible to conceive of a definite optimum balance between these micro-organisms which will be co-ordinate with maximum efficiency in the production of nitrates. If any unfavorable condition arises in the soil which unduly checks the development or functions of one kind of organism, the ultimate product of their joint activities will be correspondingly diminished.

We have seen that carbon bisulphide can materially modify the numerical or potential ratio of the various soil organisms, and other disinfectants or anaesthetics as well as heat have been found to produce similar changes. In view of the fact that these different organisms require different amounts of air and moisture, and different amounts and kinds of nutrients for their maximum development, and likewise that they are affected in varying degrees by the changing conditions of their environment, it is fair to assume that the bacterial equilibrium is constantly oscillating within certain limits. It is also apparent that while strong disinfectants may produce a marked change in the general bacterial flora of a soil, another substance of a more innocent nature may materially affect directly or indirectly one or more of the special organisms concerned in the chain of processes involved in nitrification. Lipman and Brown (New Jersey Station Report, 1907, pp. 170-186) in a series of investigations bearing on a particular soil found: "The treatment with acid phosphate led to a comparatively large increase in ammonification; a comparatively small increase in nitrification; a decrease in denitrification; and a decrease in nitrogen fixation." Again: "Muriate of potash led to a decrease in ammonification; increase in nitrification; slight decrease in denitrification; slight decrease in nitrogen fixation."



From these tests of Lipman and Brown, it is seen that certain fertilizer salts can, when applied to the soil, affect the micro-organisms which have to do with the ultimate production of nitrates and also with the bacteria which can produce denitrification. Furthermore, the same salt affects the different nitrogen bacteria, not merely to a different extent, but in one case the action may be favorable and in the case of another bacterial type it may be unfavorable; it is likewise shown that different salts act differently in this respect. Now it is reasonable to suppose that the extent to which these organisms will be affected will bear a relationship to the quantity of a particular salt added to a given soil, and it is also reasonable to suppose that through the application of several salts together, a considerable readjustment of the bacterial forces in the soil will result.

This brings us to the theory which I feel justified in advancing to explain the action of varying mixtures of fertilizer salts on crop yields as shown by the field experiments conducted by this Experiment Station with sugar cane. The theory may be briefly summed up as follows:

The relative effects of different combinations of fertilizer salts on the growth of cane, when these salts are added to the soil, will be determined chiefly by

1. The extent to which their several ingredients directly or indirectly lessen the deficiencies of available plant nutrients.
2. The extent to which they cause the bacterial flora to approach an optimum balance for the regular production of sufficient nitrates.
3. The degree and manner in which they produce physical alterations in the soil.

#### *Conformity Between Soil Analyses and Fertilizer Requirements.*

When planning the series of fertilizer experiments described in this bulletin, the idea was to have tests made on three neutral soils and three acid soils. Through force of circumstances, however, only one neutral soil was investigated, with respect to its manurial requirements when soluble salts are used, and two acid soils.

In the case of Substations B, C and D, where the soils are distinctly sour, the applications of ammonium sulphate and acid phosphate would not, in ordinary practice, be made without previous dressings of lime preparatory to planting, i. e., the first addition of fertilizing salts would follow some months after

liming. In view of the fact that these soils were not limed, it is interesting to note that while the plant cane at Substation B in the majority of cases apparently suffered from fertilization with these soluble salts, the plant cane at Substation C and D on the other hand, showed a material gain; in the case of the ratoon cane, however, the average per cent of gain from fertilization at Substation B was almost as large as that at Substation D, where a certain depressing action, doubtless due to the salts, began to be manifested.

In comparing the analyses, by the aspartic acid method, of these several soils, with the data obtained from their treatment with various combinations of sulphate of ammonia, sulphate of potash and acid phosphate, a certain conformity is observed with regard to the apparent order of importance of the several elements in fertilization, notwithstanding the many disturbing factors which enter into the results.

At Substation A, for instance, potash and phosphoric acid, while below the average for the islands, according to the agricultural method of analysis, were shown by the aspartic acid method to be relatively quite soluble, and in fact, the so-called "available" amounts of these elements were greater than the average. Furthermore, the ratio between the average percentage of these elements soluble in an one per cent solution of aspartic acid, in Hawaiian soils, and the amounts found by the same method in the soil of Substation A was slightly less with respect to potash than with phosphoric acid. The general trend of the data derived from the Substation A tests shows that while both of these elements were of small relative importance in fertilization, applications of potash were apparently more appreciated than those of phosphoric acid: increasing the potash in mixtures from 60 to 90 lbs. effected no general gain, and similar increases of phosphoric acid indicated a depressive tendency.

The nitrogen content of the Substation A soil was found by the agricultural method to be extremely low, in fact, the percentage of this element was one-half that of the average island soil: applied in fertilizer mixtures, nitrogen showed a marked beneficial effect on the yields.

The following table, showing the percentages of the elements as determined by the agricultural and aspartic acid methods will give an idea concerning the chemical composition of the substation soils with respect to the several elements under consideration, as compared with the average island soil. The detailed analyses of the different soils will be found in the appendix.

## ANALYSIS OF SOILS.

Substation Soil	Agricultural Analysis				Aspartic Acid Analysis		
	Lime	Potash	Phos. Acid	Nitrogen	Lime	Potash	Phos. Acid
Substation A.....	.66	.27	.19	.12	.103	.036	.002
Substation B.....	.39	.29	.51	.70	.176	.013	.001
Substation C & D..	.33	.40	.84	.39	.078	.011	.0003
Average for Islands	.58	.36	.26	.24	.143	.026	.0014

At Substation B the same apparent order of importance of the elements in fertilization was indicated by the field tests as was found for Substation A. Potash and phosphoric acid were both below the average for the islands, and the apparent relative shortage of potash was greater than that of phosphoric acid. The general tendency of increases in potash and phosphoric acid from 60 to 90 lbs. in mixtures was to decrease the yields, and surplus quantities of the latter element were apparently more injurious than extra quantities of the former. In referring to potash and phosphoric acid as having a certain depressive action in these several instances the writer does not mean to convey the idea that these chemical substances acted injuriously, *per se*, but rather that they, or the salts in which they were contained exerted the depressive action. In the case of the acid soil of Substation B it cannot be definitely stated that the cane showed a greater demand for potash than for phosphoric acid merely because the salt containing the latter element exerted less injury than the salt containing the former, but it is probable that the difference in the degree of harm done by increasing the respective salts was influenced in a measure by the relative requirements of the cane for the separate ingredients. The nitrogen in the soil of Substation B was found to be extremely high, but evidently from the manner in which the cane showed a general response to nitrogen applications, this element was of low availability, due to the acid nature of the soil. This affords evidence that in the case of a sour soil a very high nitrogen figure would not justify the belief that nitrogen may be omitted from fertilizers or used in only very small quantities. Lime dressings on this soil would be expected to favorably influence the availability of the natural stores of nitrogen through partially counteracting its acidity, and likewise by partially overcoming certain evil effects due to the use of soluble fertilizer salts.

In the case of the acid soil at Substations C and D the analysis figures show the nitrogen to be above the average; the quantities of potash and phosphoric acid to be greater than in the average soil, but much less soluble in the one per cent solution of aspartic acid than the run of Hawaiian soils. The phosphoric acid was furthermore found to be relatively more insoluble than the potash. The field data from both the irrigated and un-irrigated substations show a general depressive action when the potash was increased from 60 to 90 lbs. in mixtures, while a tendency towards increased yields was apparent when the phosphoric acid was similarly increased. Both substations responded very materially to the nitrogen applications, indicating that the fairly high nitrogen figure obtained by analysis was, as in the case of Substation B, not an indication that nitrogen in the form of ammonium sulphate in fertilizer mixtures would not prove effective.

In general, it may be said that the cane on the three soils, receiving their fertilizers in complete mixtures, showed a greater response to nitrogen than to potash and phosphoric acid. The order of response to nitrogen was inversely that of the nitrogen content of the soils. Where potash and phosphoric acid were each increased in mixtures to quantities above 60 lbs. per acre that element would act more unfavorably (when a depressive action occurred) which was, relatively speaking, present in more soluble quantities in the soil, the ratios between soluble quantities in the given soil and the average soil from the islands being taken as a basis for comparison.

## CONCLUSIONS.

The main conclusions reached by the writer, following a review of the data obtained from these and other fertilizer tests conducted under the direction of this Experiment Station during the past twelve years may be summed up as follows:

1. The profit resulting from the application of fertilizers or manures will depend largely upon other factors than the chemical composition of the soil. Providing certain plant food deficiencies represent the chief depressive influence on crop yields, the response to appropriate fertilization will be commensurate with the difference between the limitations exerted upon crop production through lack of available plant nutrients and the limitations exercised by the next restraining factor in order or im-

portance after the material has been applied. This latter factor may be physical, biological or climatic in character.

2. The relative effects of different combinations of fertilizer materials on the growth of sugar cane when these materials are added to a given soil will be determined chiefly by

(a) the extent to which their several ingredients directly or indirectly lessen the deficiencies of available plant nutrients;

(b) the extent to which they cause the bacterial flora to approach an optimum balance for the regular production of sufficient nitrates or assimilable nitrogen compounds, and

(c) the degree and manner in which they produce physical changes in the soil.

3. Owing to the fact that a definite relationship exists between the efficiency of a fertilizer mixture and the quantities and proportions in which its ingredients are associated, due to biological, chemical and physical effects which its component parts have in a given soil, variations in the composition of the mixture beyond certain limits may materially influence crop yields.

4. A more definite knowledge concerning the amounts and proportions of fertilizer salts to use in a mixture for best results would on some soils yield pronounced profits, while a lack of such knowledge may in some cases result in a loss, especially when soluble salts are employed.

5. The greatest loss from the use of improper mixtures of fertilizers is apt to occur on acid soils, and in such cases considerable risk is involved from the continued application of mixtures containing ammonium sulphate, sulphate of potash, and acid phosphate, when lime dressings are not previously made.

6. While the chemical and physical analysis of a soil will usually prove of value in indicating the best cultural methods to follow in maintaining or improving its fertility, and may also indicate in a general way certain of the plant food deficiencies in given cases, it cannot afford definite information as to the amounts or proportions of ingredients in fertilizer mixtures which will give maximum returns.

7. It is possible that the data from more extended field experiments with a large variety of soils, when reviewed in connection with the comparative analysis of the soils, using both weak and strong acids as solvents may indicate a somewhat definite relationship between the analytical figures and the order of importance which phosphoric acid and potash should assume in cane fertilizers in given cases.

8. It would appear that analysis of soils, with more special reference to their physical qualities, reaction and content of organic matter, nitrogen, and more readily soluble lime, may, with due consideration of the water supply and climatic conditions, be relied upon to indicate such manurial treatment as will result in a profit, although they will not afford definite information as to the weights and proportions of ingredients in fertilizer mixtures which will result in maximum efficiency.

9. Nitrogen is the most important element to be considered in the fertilization of the sugar cane in the Hawaiian Islands, and when applied in mixed fertilizers some risk of reduced efficiency is entailed if either the potash or phosphoric acid (in the form of soluble salts) is made to exceed the weight of this element.

10. Unless through past local experience or carefully conducted field tests it has been definitely determined that a modified formula may be expected to give greater yields, it is safer, when applying nitrogen, potash and phosphoric acid in the form of soluble salts, to have the mixed fertilizer contain even quantities of these elements, which are not to exceed 60 lbs. per acre in the case of each element.

11. Field tests with fertilizers whose ingredients are mixed in varying proportions will, if such experiments are accurately and scientifically conducted through a sufficient period, give the most reliable information as to the best manurial practice. Such experiments should be laid out in very long, narrow, parallel and contiguous plats or strips, with the untreated check areas lying immediately adjacent to the fertilized cane, as described in the appendix of Circular No. 6, of this Division.

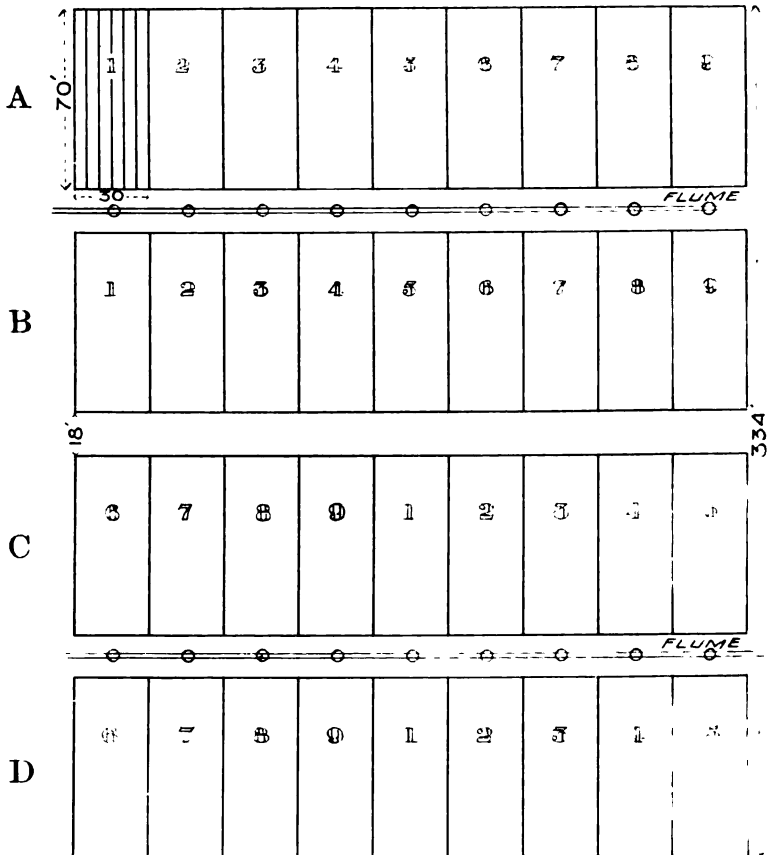
12. The great importance of "resting" fields in rotation on Hawaiian plantations, and growing upon them leguminous crops is very clearly indicated. This applies more particularly to the irrigated plantations, where the supplies of organic matter are in the majority of cases becoming greatly reduced through successive tillage operations in a comparatively arid climate, and by the favorable conditions created for bacterial activity through regular irrigations under uniformly high temperatures.

## APPENDIX.

In the following pages are given the data which formed the basis for the calculated results presented in this bulletin. In addition thereto are rainfall and temperature records, and notes concerning the treatment of the various substations where this was recorded.

### SUBSTATION A.

DIAGRAM OF EXPERIMENT PLATS.



## ANALYSIS OF SOIL OF SUBSTATION A.

The soil of this substation is a red clayeo loam of from four to six feet in depth, and good natural drainage. Its composition is indicated by the following analysis:

*Mechanical Analysis.*

Loss on ignition.....	22.03
Coarse Grits.....	
Fine     ".....	
Coarse Sand.....	.01
Medium   ".....	1.33
Fine       ".....	32.86
Silt .....	26.86
Fine Silt.....	12.94
Clay .....	3.14
<hr/>	
Total.....	99.17

*Agricultural Analysis.*

Combined water and organic matter...	12.58
Insoluble residue.....	37.80
Iron Oxide ( $\text{Fe}_2\text{O}_3$ ) .....	21.61
Alumina ( $\text{Al}_2\text{O}_3$ ) .....	25.92
Lime ( $\text{CaO}$ ) .....	.66
Magnesia ( $\text{MgO}$ ) .....	.63
Potash ( $\text{K}_2\text{O}$ ) .....	.27
Soda ( $\text{Na}_2\text{O}$ ) .....	.30
Sulphuric anhydride.....	.19
Phosphoric anhydride.....	.19
Chlorine .....	.015
<hr/>	
Total.....	100.235

Nitrogen .....	.12
Soluble silica.....	22.35
Humus .....	3.75
Nitrogen in humus.....	3.76
Absorptive power.....	39.00
Moisture in air dry soil.....	10.72
Reaction .....	neutral



*Aspartic Acid Analysis.*

Lime .....	.103
Potash.....	.036
Phosphoric acid.....	.002
Nitrogen .....	.12
Moisture in air dry soil.....	10.72

*Slope of Field.*

This experiment area was very nearly level, the greatest fall being 14 inches between two diagonally opposite corners.

## PLANT CANE TESTS AT SUBSTATION A.

*Preparation of Land for Planting.*

The previous crop on this land was harvested in December, 1904, the field remaining fallow and uncleared until April, 1905, when the trash was burned off. It was then steam plowed to a depth of 20 inches, and replowed in June, 1905.

*Planting.*

Furrows were opened up with a mould board plow, and planted with Lahaina cane on August 24, 1905.

*Treatment of Plats.*

The first four irrigations consisted of 1.6 inches (350 gallons per furrow) of water on the day of planting, and the same quantity at succeeding intervals on two (five and six days). After the first four irrigations the same volume was applied weekly until the end of the fourth month, when the quantity was increased to 2.4 inches (525 gallons per furrow); this latter volume was applied until one month before irrigation was discontinued, when it was increased to 3.2 inches (700 gallons per furrow.) The same measured quantity of water was applied to all of the plats.

The experiment area was weeded in September and December, 1905, and fertilizer was applied on October 26, 1905, and April 6, 1906.

*Weather Conditions.*

The temperature and rainfall at Substation A during the progress of the plant cane experiments are shown in the following table. The temperatures are for the period between August 1, 1905, and March 30, 1907, and the figures for rainfall represent the precipitations between the dates of planting and harvesting.

## TEMPERATURE AND RAINFALL AT SUBSTATION A.

MONTH	Temperature			Rainfall. Inches
	Max.	Min.	Mean	
August, 1905..	86.4	70.6	78.5	.12
Sept. ....	86	69	77.5	1.49
Oct. ....	86.7	67	76.8	.05
Nov. ....	88	65	76.5	.38
Dec. ....	86	64	75	1.39
Jan., 1906....	83	60	71.5	1.38
Feb. ....	84	60	72	.19
Mar. ....	82	59	72	3.14
April ....	85	63	74	.50
May ....	85	66	76	.53
June ....	85	66	76	.....
July ....	87	70	78.5	.17
Aug. ....	89	71	80	.56
Sept. ....	89	69	79	.12
Oct. ....	89	69	79	1.24
Nov. ....	88	64	76	3.02
Dec. ....	83	64	73.5	10.20
Jan., 1907....	82	65	73.5	9.11
Feb. ....	82	63	72.5	5.33
Mar. ....	86	56	73	1.12
Average ....	85.6	65.0	75.5	40.04 (total)

*Harvesting of Plant Cane on the Experiment Plats.*

The cane on the two middle furrows of each plat was cut and weighed, and the juice tested, on March 18th and 19th, 1907. The yields of cane and sugar, as well as the quality of the juices, were calculated from the results obtained from corresponding plats in the duplicate series of tests. For instance, the weight of cane on the two test rows of Plat No. 1, Division A, was 1397 lbs., and on Plat No. 1, Division C, 1434 lbs.; the total weight harvested from an aggregate area of 1400 sq. ft. was therefore 2831 lbs., or at the rate of 44.04 tons per acre for Plat No. 1.

## STATEMENTS OF CANE WEIGHTS AND JUICE ANALYSIS.

*Weights of Plant Cane.*      Harvested March 18 and 19, 1907.

Plat	Area Cut Square Feet	Weight of Cane Lbs.	Plat	Area Cut Square Feet	Weight of Cane Lbs.
A 1	700	1397	C 1	700	1434
A 2	"	1261	C 2	"	1260
A 3	"	1438	C 3	"	985
A 4	"	1775	C 4	"	1314
A 5	"	1546	C 5	"	1405
A 6	"	1458	C 6	"	1401
A 7	"	1301	C 7	"	1459
A 8	"	1552	C 8	"	1524
A 9	"	1375	C 9	"	1225
B 1	"	950	D 1	"	968
B 2	"	1025	D 2	"	906
B 3	"	1101	D 3	"	935
B 4	"	1035	D 4	"	986
B 5	"	1141	D 5	"	869
B 6	"	824	D 6	"	869
B 7	"	932	D 7	"	716
B 8	"	969	D 8	"	916
B 9	"	957	D 9	"	845

The areas and cane weights given above are correct.

Signed.      E. G. CLARKE,  
For Experiment Station, H. S. P. A.

## ANALYSIS OF JUICE FROM PLANT CANE.

Plat	Brix	Sucrose	Purity	Plat	Brix	Sucrose	Purity
A 1	23.09	21.57	93.42	C 1	22.65	21.43	94.62
A 2	22.38	20.90	93.39	C 2	23.05	21.84	94.75
A 3	22.18	20.78	93.69	C 3	23.16	21.87	94.43
A 4	22.65	21.25	93.82	C 4	23.26	21.84	93.89
A 5	22.28	20.78	93.27	C 5	22.38	20.97	93.70
A 6	22.48	21.29	94.71	C 6	22.11	20.86	94.35
A 7	22.25	20.75	93.21	C 7	22.11	20.78	93.98
A 8	22.79	21.51	94.38	C 8	22.15	20.78	93.81
A 9	22.15	20.70	93.45	C 9	22.28	20.99	94.21
B 1	22.65	21.21	93.69	D 1	22.48	21.18	94.22
B 2	22.45	21.10	93.99	D 2	22.59	21.59	95.57
B 3	22.35	21.03	94.09	D 3	22.55	21.35	94.68
B 4	22.75	21.39	94.02	D 4	22.42	21.40	95.45
B 5	22.55	21.10	93.57	D 5	22.48	21.55	95.86
B 6	23.05	21.77	94.45	D 6	22.12	20.96	94.76
B 7	22.35	21.19	94.81	D 7	22.32	21.15	94.76
B 8	22.55	21.36	94.72	D 8	22.22	21.16	95.23
B 9	22.95	21.70	94.55	D 9	22.59	21.32	94.38

Fiber % Cane (approximate)—10.85.

Signed. A. E. JORDAN.

Assistant Chemist, Experiment Station, H. S. P. A.

## RATOON CANE TESTS AT SUBSTATION A.

*Cutting Back.*

The cane in these experiments was cut back on July 1, 1907.

*Treatment of Plats.*

The ratoons were weeded September 2, 1907, and hilled up and weeded again on November 11, 1907. Fertilizer was applied November 4, 1907, and February 9, 1908. The irrigation of the plats was as follows:

Period	No. of Irrigations	Quantity of Water per Irrigation
1907, July 1 to Oct. 15, incl.	16	2.0 inches
Oct. 21, 1907, to Mar. 2, 1908	17	1.5 "
Mar. 2, 1908, to Sept. 14, 1908	29	2.0 "
Sept. 14, 1908, to Feb. 8, 1909	20	3.0 "

*Weather Conditions.*

The temperature and rainfall at Substation A during the progress of the ratoon cane experiments are shown in the following table.

## TEMPERATURE AND RAINFALL AT SUBSTATION A.

MONTH	Temperature			Rainfall Inches
	Max.	Min.	Mean	
July, 1907.....	89	62	75.5	.43
Aug. ....	92	65	78.5	2.96
Sept. ....	94	66	80.0	.66
Oct. ....	90	58	74.0	.46
Nov. ....	91	55	73.0	.84
Dec. ....	91	55	73.0	.40
Jan., 1908.....	88	55	71.5	.21
Feb. ....	88	54	71.0	1.25
Mar. ....	87	57	72.0	1.57
April ....	87	59	73.0	.07
May ....	87	58	72.5	....
June ....	86	60	73.0	....
July ....	89	65	77.0	.14
Aug. ....	87	63	75.0	....
Sept. ....	89	63	76.0	.43
Oct. ....	92	64	78.0	.08
Nov. ....	90	57	73.5	1.55
Dec. ....	86	57	71.5	1.19
Jan., 1909.....	86	54	70.0	.22
Feb. ....	86	54	70.0	4.53
Mar. ....	79	63	71.0	.24
Average.....	88.3	59.2	73.7	17.23 (TOTAL)

*Harvesting of Ratoon Cane on the Experiment Plats.*

The cane on the middle two rows of each plat was cut and weighed and the juice tested, March 3, 1909.

STATEMENTS OF CANE WEIGHTS AND JUICE ANALYSIS.

*Weights of Ratoon Cane, lbs.*

Harvested March 3, 1909.

PLAT	Fertilized Test Area	Weight of Cane	No. of Dead Canes	PLAT	Unfertilized Test Area	Weight of Cane	No. of Dead Canes
A 1	400 sq. ft.	686	2	B 1	400 sq. ft.	421	—
A 2	" "	697	—	B 2	" "	419	—
A 3	" "	779	—	B 3	" "	421	—
A 4	" "	976	—	B 4	" "	416	—
A 5	" "	900	—	B 5	" "	462	—
A 6	" "	1006	—	B 6	" "	414	—
A 7	" "	788	1	B 7	" "	488	4
A 8	" "	952	5	B 8	" "	451	—
A 9	" "	793	1	B 9	" "	441	—
C 6	" "	727	—	D 6	" "	415	—
C 7	" "	665	—	D 7	" "	331	—
C 8	" "	855	—	D 8	" "	447	—
C 9	" "	723	—	D 9	" "	405	—
C 1	" "	773	2	D 1	" "	394	—
C 2	" "	716	—	D 2	" "	428	—
C 3	" "	754	—	D 3	" "	408	—
C 4	" "	921	—	D 4	" "	429	—
C 5	" "	828	—	D 5	" "	413	—

The area and cane weights given above are correct.

Sgnd. JAMES H. WALE.  
For Experiment Station, H. S. P. A.



## ANALYSIS OF JUICES FROM RATOON CANE.

PLAT	Brix	Sucrose	Purity	PLAT	Brix	Sucrose	Purity
A 1	22.0	21.0	95.5	B 1	22.1	21.0	95.0
A 2	22.2	21.3	95.9	B 2	22.1	21.3	96.4
A 3	22.1	21.0	95.0	B 3	21.9	20.7	94.5
A 4	21.5	20.7	96.3	B 4	22.2	21.1	95.0
A 5	22.1	21.3	96.4	B 5	21.7	21.0	96.8
A 6	21.6	20.6	95.4	B 6	22.0	21.0	95.5
A 7	22.3	21.6	96.9	B 7	22.2	21.2	95.5
A 8	22.5	21.4	95.1	B 8	22.1	21.3	96.4
A 9	21.9	21.1	96.3	B 9	21.9	21.0	95.9
C 6	21.2	20.3	95.8	D 6	21.6	20.8	96.3
C 7	22.4	21.3	95.1	D 7	20.8	20.1	96.6
C 8	22.5	21.6	96.0	D 8	20.9	20.2	96.7
C 9	22.2	21.3	95.9	D 9	21.2	20.2	95.3
C 1	21.7	21.0	96.8	D 1	21.7	21.0	96.8
C 2	22.5	21.4	95.1	D 2	21.7	20.8	95.9
C 3	21.9	21.1	96.3	D 3	22.1	21.1	95.5
C 4	22.1	21.1	95.5	D 4	22.2	21.1	95.0
C 5	22.2	21.5	96.8	D 5	22.3	21.2	95.1

Sgnd. R. S. NORRIS,  
Asst. Chemist, Experiment Station, H. S. P. A.

DATA CONCERNING THE YIELDS OF CANE AND SUGAR AT SUB-  
STATION A.

YIELDS OF CANE ON THE FERTILIZED AND UNFERTILIZED PLATS.

PLANT CANE.

PLAT No.	Fertilization. Lbs. per Acre			Area Cut Sq. Ft.	Weight of Cane. Lbs.	
	Nitrogen	Potash	Phos. Acid		Fertilized	Not Fertilized
1	60	60	60	1400	2831	1918
2	60	60	90	"	2521	1931
3	60	90	60	"	2423	2036
4	90	60	60	"	3089	2021
5	90	90	60	"	2951	2010
6	90	60	90	"	2859	1693
7	60	90	90	"	2760	1648
8	90	90	90	"	3076	1885
9	60	60	none	"	2600	1802

RATOONS.

PLAT No.	Fertilization. Lbs. per Acre			Area Cut Sq. Ft.	Weight of Cane. Lbs.	
	Nitrogen	Potash	Phos. Acid		Fertilized	Not Fertilized
1	60	60	60	800	1459	815
2	60	60	90	"	1413	847
3	60	90	60	"	1533	820
4	90	60	60	"	1897	845
5	90	90	60	"	1728	875
6	90	60	90	"	1733	829
7	60	90	90	"	1453	819
8	90	90	90	"	1807	898
9	60	60	none	"	1516	846

## YIELDS OF PLANT CANE PER ACRE.

PLAT No.	Fertilization, Lbs. per Acre			Cane per Acre. Tons		Gain From Fertilization Per Cent.
	Nitro- gen	Potash	Phos. Acid	Fertilized	Not Fertilized	
1	60	60	60	44.04	29.84	47.6
2	60	60	90	39.22	30.04	30.6
3	60	90	60	37.69	31.67	19.0
4	90	60	60	48.06	31.44	52.9
5	90	90	60	45.91	31.27	46.8
6	90	60	90	44.48	26.34	68.9
7	60	90	90	42.94	25.64	67.5
8	90	90	90	47.85	29.32	63.2
9	60	60	none	40.45	28.03	44.3

## YIELDS OF RATOONS PER ACRE.

PLAT No.	Fertilization, Lbs. per Acre			Cane per Acre. Tons		Gain from Fertilization Per Cent.
	Nitrogen	Potash	Phos. Acid	Fertilized	Not Fertilized	
1	60	60	60	39.72	22.19	79.0
2	60	60	90	38.47	23.06	66.8
3	60	90	60	41.73	22.57	84.9
4	90	60	60	51.64	23.00	124.5
5	90	90	60	47.04	23.87	97.1
6	90	60	90	47.18	22.57	109.0
7	60	90	90	39.56	22.30	77.4
8	90	90	90	49.19	24.45	101.2
9	60	60	none	41.27	23.03	79.2

## SUCROSE IN JUICE. PERCENT.

## PLANT AND RATOONS.

PLAT No.	Fertilization. Lbs. per Acre			Plant Cane		Ratoons	
	Nitrogen	Potash	Phos. Acid	Fertilized	Not Fertilized	Fertilized	Not Fertilized
1	60	60	60	21.5	21.2	21.0	21.0
2	60	60	90	21.4	21.3	21.3	21.0
3	60	90	60	21.3	21.2	21.0	20.9
4	90	60	60	21.5	21.4	20.9	21.1
5	90	90	60	20.9	21.3	21.4	21.1
6	90	60	90	21.1	21.4	20.4	20.9
7	60	90	90	20.8	21.2	21.4	20.6
8	90	90	90	21.1	21.3	21.5	20.7
9	60	60	none	20.8	21.5	21.2	20.6

## PURITY OF JUICE. PLANT AND RATOONS.

PLAT No.	Fertilization. Lbs. per Acre			Plant Cane		Ratoons	
	Nitrogen	Potash	Phos. Acid	Fertilized	Not Fertilized	Fertilized	Not Fertilized
1	60	60	60	94.0	93.0	96.1	95.9
2	60	60	90	94.1	94.8	95.5	96.1
3	60	90	60	94.0	94.4	95.6	95.0
4	90	60	60	93.9	94.7	95.9	95.0
5	90	90	60	93.5	94.7	96.6	95.9
6	90	60	90	94.5	94.6	95.6	95.9
7	60	90	90	93.6	94.8	96.0	96.0
8	90	90	90	94.1	95.0	95.5	96.5
9	60	60	none	93.8	94.5	96.1	95.6

## AVAILABLE\* SUGAR PER ACRE. TONS.

## PLANT AND RATOONS.

PLAT No.	Fertilization, Lbs. per Acre.			Plant Cane		Ratoons	
	Nitro- gen	Potash	Phos. Acid	Fertil- ized	Not Fertilized	Fertil- ized	Not Fertilized
1	60	60	60	7.38	4.92	6.57	3.66
2	60	60	90	6.53	5.01	6.44	3.82
3	60	90	60	6.23	5.23	6.90	3.60
4	90	60	60	8.05	5.26	8.50	3.80
5	90	90	60	7.45	5.20	7.94	3.95
6	90	60	90	7.32	4.40	7.59	3.71
7	60	90	90	6.94	4.25	6.68	3.64
8	90	90	90	7.90	4.87	8.30	4.00
9	60	60	none	6.56	4.71	6.89	3.73

## GAIN IN AVAILABLE SUGAR FROM FERTILIZATION.

## PLANT AND RATOONS.

PLAT No.	Fertilization, Lbs. per Acre			Plant Cane		Ratoons	
	Nitro- gen	Potash	Phos. Acid	Tons	Per Cent.	Tons	Per Cent.
1	60	60	60	2.46	50.0	2.91	79.5
2	60	60	90	1.52	30.3	2.62	68.6
3	60	90	60	1.00	19.1	3.21	87.0
4	90	60	60	2.79	53.0	4.70	123.7
5	90	90	60	2.25	43.3	3.99	101.0
6	90	60	90	2.92	66.4	3.88	104.6
7	60	90	90	2.69	63.3	3.04	83.5
8	90	90	90	3.03	62.2	4.30	107.5
9	60	60	none	1.85	39.3	3.16	84.7

\* To obtain available sugar the sucrose in the expressed juice is multiplied by the factor .8 (1.4—<sup>40</sup> Purity). The weights of available sugar as given for the plant cane in Circular No. 6 have in this bulletin been modified in accordance with this more satisfactory formula.

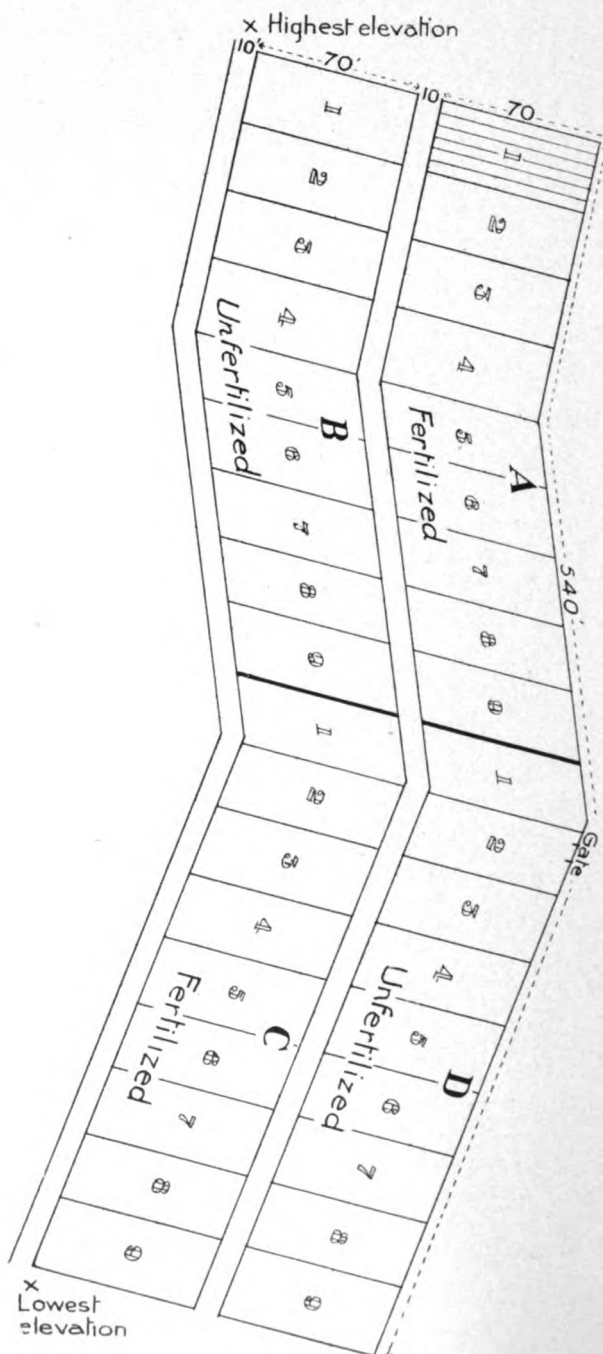
## GAIN IN AVAILABLE SUGAR FROM FERTILIZATION.

## AVERAGE OF PLANT AND RATOONS.

PLAT No.	Fertilization. Lbs. per Acre.			Average Gain		Basis
	Nitrogen	Potash	Phos. Acid	Tons	Per Cent.	Tons
1	60	60	60	2.68	62.5	4.29
2	60	60	90	2.07	46.9	4.41
3	60	90	60	2.10	47.1	4.46
4	90	60	60	3.74	82.5	4.53
5	90	90	60	3.12	68.2	4.57
6	90	60	90	3.40	83.9	4.05
7	60	90	90	2.86	72.6	3.94
8	90	90	90	3.66	82.6	4.43
9	60	60	none	2.50	59.2	4.22

# SUBSTATION B. (Elevation 1250 feet.)

DIAGRAM OF EXPERIMENT PLATS.



## ANALYSIS OF SOIL OF SUBSTATION B.

The soil of this substation is a dark friable loam of about 13 inches depth, underlaid by three feet of dark yellow subsoil resting on "Aa." The composition of the top soil is indicated by the following analytical data:

*Mechanical Analysis.*

Loss on ignition .....	36.01
Coarse grits .....	.55
Fine grits .....	.66
Coarse sand .....	.29
Medium sand .....	2.11
Fine sand .....	10.47
Coarse silt .....	32.68
Fine silt .....	14.61
Clay .....	2.16
<hr/>	
Total .....	99.54

*Agricultural Analysis.*

Combined water and organic matter..	26.16
Insoluble residue .....	32.72
Ferric oxide ( $\text{Fe}_2\text{O}_3$ ) .....	18.98
Alumina ( $\text{Al}_2\text{O}_3$ ) .....	19.99
Lime ( $\text{CaO}$ ) .....	.39
Magnesia ( $\text{MgO}$ ) .....	.70
Potash ( $\text{K}_2\text{O}$ ) .....	.29
Soda ( $\text{Na}_2\text{O}$ ) .....	.21
Sulphuric anhydride .....	.20
Phosphoric anhydride .....	.51
Chlorine .....	.018
<hr/>	
Total .....	100.168

Nitrogen .....	.70
Soluble silica .....	12.09
Humus .....	11.01
Nitrogen in Humus .....	4.36
Absorptive power .....	58.16
Moisture in air dry soil .....	14.03
Reaction .....	acid ..



*Aspartic Acid Analysis.*

Lime .....	.176
Potash .....	.013
Phosphoric acid .....	.001
Nitrogen .....	.68
Moisture in air dry soil.....	14.92

## Slope of Field.

The experiment area had a 10% grade running practically due north and south.

## PLANT CANE TESTS AT SUBSTATION B.

## Preparation of Land for Planting.

The field was steam plowed to a depth of 15 inches and then harrowed with a large mule harrow. The rows were opened up with a double mould-board plow and a small cultivator was run along bottoms of furrows to prepare the seed bed.

## Planting.

Planting was performed on May 1, 1905, with the Yellow Caledonia variety.

## Treatment of Plats.

The treatment given the plats of this substation, as recorded, was as follows:

First hoeing, June 24, 1905.

Cultivated with Horner's cultivator, July 20, 1905.

Second hoeing and first fertilizing, July 30, 1905.

Cultivated with small plows, August 5, 1905.

Cultivated with Horner's cultivator, August 16, 1905.

Cultivated with Horner's cultivator, Sept. 9, 1905.

Cultivated with small plow and hiller, Sept. 16, 1905.

Third hoeing, Nov. 21, 1905.

First stripping, June 17, 1906.

Second stripping, Dec. 20, 1906.

## Weather Conditions.

No rainfall or temperature records were kept at the elevation at which the substation was located, but the following data derived from rainfall and temperature observations at the plantation office, elevation 350 feet and the adjacent plantation 1100 feet, give some idea of the weather conditions which prevailed during the progress of the experiments.

## TEMPERATURE AND RAINFALL RECORD.

MONTH	Temperature			Rainfall	
	Max.	Min.	Mean	350 Feet	Adjacent Plantation 1,100 Feet
May, 1905 .....	80	66	73	5.00	7.04
June .....	81	67	74	3.10	4.65
July .....	82	69	75	5.07	8.34
Aug. ....	81	70	76	6.48	8.04
Sept. ....	82	70	76	11.19	18.70
Oct. ....	82	68	75	3.97	6.98
Nov. ....	81	66	73	5.81	6.14
Dec. ....	79	62	71	6.38	9.24
Jan., 1906 .....	85	59	71	.96	1.98
Feb. ....	86	56	72	.85	2.19
Mar. ....	84	56	71	2.02	2.97
April ....	86	62	73	7.60	8.68
May ....	85	62	73	2.94	7.04
June ....	89	64	75	1.39	1.68
July ....	88	65	75	7.85	9.74
Aug. ....	87	65	75	9.10	11.17
Sept. ....	89	64	76	1.47	1.84
Oct. ....	89	63	75	1.09	1.07
Nov. ....	86	60	72	6.02	7.65
Dec. ....	84	58	70	5.31	18.51
Jan., 1907 .....	80	62	71	3.02	1.91
Feb. ....	78	62	70	9.62	8.79
Mar. ....	79	61	70	8.34	....
Average .....	83.6	63.3	73.1	124.58*	161.07*

\*Total rainfall.

*Harvesting of Plant Cane on the Experiment Plots.*

The cane on the test rows was cut and weighed and the juice tested on the 25th and 26th of March, 1907.

## STATEMENTS OF CANE WEIGHTS AND JUICE ANALYSIS.

*Weights of Plant Cane.*      Harvested March 25 and 26, 1907.

PLAT	Area Cut		Wt. of Cane		PLAT	Area Cut		Wt. of Cane	
	Sq. Ft.	Lbs.				Sq. Ft.	Lbs.		
A 1	700	1310			C 1	700	1747		
A 2	"	1006			C 2	"	1549		
A 3	"	1257			C 3	"	1590		
A 4	"	1211			C 4	"	1483		
A 5	"	1493			C 5	"	1634		
A 6	"	1681			C 6	"	1620		
A 7	"	1519			C 7	"	1287		
A 8	"	1441			C 8	"	1526		
A 9	"	1437			C 9	"	1322		
B 1	"	1348			D 1	"	1482		
B 2	"	1367			D 2	"	1359		
B 3	"	1009			D 3	"	1343		
B 4	"	1174			D 4	"	1739		
B 5	"	1262			D 5	"	1532		
B 6	"	1032			D 6	"	1566		
B 7	"	1521			D 7	"	1624		
B 8	"	1718			D 8	"	1745		
B 9	"	1566			D 9	"	1560		

The areas and cane weights given above are correct.

Signed.      E. G. CLARKE.

For Experiment Station, H. S. P. A.

## ANALYSIS OF JUICE FROM PLANT CANE.

Plat	Brix	Sucrose	Purity	Plat	Brix	Sucrose	Purity
A 1	20.05	18.43	91.92	C 1	19.74	18.05	91.44
A 2	20.38	18.89	92.69	C 2	19.84	17.98	90.63
A 3	21.38	18.81	87.98	C 3	20.24	18.50	91.40
A 4	19.68	18.02	91.56	C 4	20.14	18.48	91.76
A 5	20.28	18.84	92.90	C 5	20.38	18.79	92.20
A 6	19.89	18.00	90.50	C 6	19.98	18.35	91.84
A 7	20.59	18.69	90.77	C 7	20.81	19.20	92.26
A 8	20.49	18.71	91.31	C 8	20.71	19.20	92.71
A 9	20.91	19.20	91.82	C 9	20.71	19.20	92.71
B 1	20.14	18.43	91.51	D 1	20.58	19.11	92.86
B 2	20.44	19.00	92.95	D 2	20.38	19.03	93.38
B 3	20.78	19.20	92.40	D 3	20.28	18.89	93.15
B 4	20.78	19.38	93.26	D 4	20.75	19.20	92.96
B 5	20.48	18.87	92.14	D 5	20.65	19.03	92.15
B 6	20.38	18.87	92.59	D 6	20.65	19.14	92.69
B 7	20.48	19.03	92.92	D 7	20.78	19.16	92.20
B 8	19.84	18.11	91.28	D 8	20.48	19.00	92.77
B 9	20.54	18.76	91.33	D 9	20.28	18.88	93.10

Fiber % Cane (approximate)=12.00.

Signed. A. E. JORDAN.

Assistant Chemist, Experiment Station, H. S. P. A.

## RATOON CANE TESTS AT SUBSTATION B.

*Start of Ratoons.*

The starting of the ratoons was coincident with the harvesting of the plant cane, March 25, 1907.

*Treatment of Plats.*

The plats were fertilized August 19, 1907, and February 21, 1908. Hoeing was performed August 19, Sept. 18, and Dec. 9, 1907, and on Feb. 21, 1908. Cultivation with small plow and harrows was practiced July 12 and 18, Aug. 19, Sept. 23, Oct. 3 and 24, and Dec. 7, 1907.

*Weather Conditions.*

The rainfall and temperature record from date plant cane was harvested until end of Feb. 1909, was as follows:

## TEMPERATURE AND RAINFALL AT SUBSTATION B.

Month	Mean Temp.	Rainfall
March, 1907 .....	64.3	10.50
April .....	65.7	10.31
May .....	70.0	2.19
June .....	71.3	1.98
July .....	70.8	10.30
August .....	69.9	25.03
September .....	71.5	12.48
October .....	69.0	8.81
November .....	67.4	5.21
December .....	66.6	2.92
January, 1908 .....	65.0	4.80
February .....	67.0	5.11
March .....	69.0	7.15
April .....	65.0	8.48
May .....	67.7	3.00
June .....	72.0	1.70
July .....	69.0	8.32
August .....	69.0	7.10
September .....	67.0	8.28
October .....	64.0	6.11
November .....	64.5	7.88
December .....	63.0	23.81
January, 1909 .....	64.0	5.78
February .....	62.7	12.68
Average .....	67.3	Total 199.93

*Harvesting Ratoon Cane on Experiment Plats.*

The cane on the middle two rows of each plat was out and weighed and the juice tested, March 9 and 10, 1909.

## STATEMENTS OF CANE WEIGHTS AND JUICE ANALYSIS.

*Weights of Ratoon Cane.* Harvested March 9 and 10, 1909.

PLAT	Fertilizer Test Area	Weight of Cane	No. of Dead Canes	PLAT	Unfertilized Test Area	Weight of Cane	No. of Dead Canes
A 1	700 sq. ft.	885	6	B 1	700 sq. ft.	764	3
A 2	" "	638	3	B 2	" "	815	1
A 3	" "	648	4	B 3	" "	542	0
A 4	" "	819	2	B 4	" "	624	0
A 5	" "	884	1	B 5	" "	704	1
A 6	" "	1070	2	B 6	" "	572	0
A 7	" "	912	1	B 7	" "	666	0
A 8	" "	1012	3	B 8	" "	932	4
A 9	" "	714	2	B 9	" "	821	2
C 1	" "	1314	2	D 1	" "	881	4
C 2	" "	1146	0	D 2	" "	868	4
C 3	" "	866	2	D 3	" "	756	2
C 4	" "	1057	1	D 4	" "	753	2
C 5	" "	1153	1	D 5	" "	868	1
C 6	" "	1096	4	D 6	" "	705	2
C 7	" "	741	4	D 7	" "	762	2
C 8	" "	1046	2	D 8	" "	861	2
C 9	" "	847	4	D 9	" "	760	3

The area and cane weights given above are correct.

Signed. E. G. CLARKE,

For Experiment Station, H. S. P. A.

## ANALYSIS OF JUICES FROM RATOON CANE.

Plat	Brix	Sucrose	Purity	Plat	Brix	Sucrose	Purity
A 1	20.67	19.05	92.16	B 1	19.86	18.45	92.90
A 2	20.57	18.85	91.64	B 2	20.46	18.90	92.38
A 3	20.57	19.10	92.85	B 3	20.56	18.90	91.93
A 4	20.70	19.15	92.51	B 4	20.14	18.65	92.61
A 5	20.80	19.55	93.99	B 5	19.96	18.45	92.43
A 6	20.60	19.20	93.20	B 6	20.26	18.85	93.04
A 7	20.83	19.45	93.38	B 7	20.20	18.85	93.32
A 8	20.75	19.25	92.86	B 8	20.56	19.15	93.14
A 9	20.93	19.45	92.93	B 9	20.20	18.90	93.57
C 1	20.06	18.85	93.97	D 1	20.63	19.30	93.55
C 2	20.83	19.60	94.09	D 2	20.03	18.40	91.86
C 3	20.40	19.20	94.12	D 3	20.23	18.70	92.44
C 4	20.40	19.05	93.38	D 4	20.73	19.10	92.14
C 5	20.80	19.60	94.23	D 5	20.33	19.00	93.46
C 6	20.80	19.60	94.23	D 6	20.90	19.15	91.63
C 7	20.40	19.20	94.12	D 7	20.70	19.35	93.48
C 8	20.80	19.35	93.03	D 8	20.60	19.15	92.96
C 9	20.56	19.25	93.63	D 9	20.26	18.55	91.56

Signed. A. E. JORDAN,  
 Assistant Chemist, Experiment Station, H. S. P. A.

# DATA CONCERNING THE YIELDS OF CANE AND SUGAR AT SUBSTATION B.

## YIELDS OF CANE ON THE FERTILIZED AND UNFERTILIZED PLATS.

### PLANT CANE.

PLAT No.	Fertilization. Lbs. per Acre			Area Cut Sq. Ft.	Weights of Cane. Pounds	
	Nitrogen	Potash	Phos. Acid		Fertilized	Not Fertilized
1	60	60	60	1400	3057	2830
2	60	60	90	"	2555	2726
3	60	90	60	"	2847	2352
4	90	60	60	"	2694	2913
5	90	90	60	"	3127	2704
6	90	60	90	"	3301	2598
7	60	90	90	"	2806	3145
8	90	90	90	"	2967	3463
9	60	60	none	"	2759	3126

### RATOONS.

PLAT No.	Fertilization. Lbs. per Acre			Area Cut Sq. Ft.	Weights of Cane. Pounds	
	Nitrogen	Potash	Phos. Acid		Fertilized	Not Fertilized
1	60	60	60	1400	2199	1645
2	60	60	90	"	1784	1683
3	60	90	60	"	1514	1298
4	90	60	60	"	1876	1377
5	90	90	60	"	2037	1572
6	90	60	90	"	2166	1277
7	60	90	90	"	1653	1428
8	90	90	90	"	2058	1793
9	60	60	none	"	1561	1581



## YIELDS OF PLANT CANE PER ACRE.

PLAT No.	Fertilization, Lbs. per Acre			Gain per Acre, Tons		Gain or Loss from Fertilization, Percent.
	Nitrogen	Potash	Phos. Acid	Fertil- ized	Not Fertilized	
1	60	60	60	47.56	44.03	+ 8.0
2	60	60	90	39.75	42.41	— 6.3
3	60	90	60	44.29	36.59	+21.0
4	90	60	60	41.91	45.32	— 7.5
5	90	90	60	48.65	43.47	+11.9
6	90	60	90	51.35	40.42	+27.0
7	60	90	90	43.65	48.93	—10.8
8	90	90	90	46.16	53.87	—14.3
9	60	60	none	42.92	48.63	—11.7

## YIELDS OF RATOONS PER ACRE.

PLAT No.	Fertilization, Lbs. per Acre			Gain per Acre, Tons		Gain or Loss from Fertilization, Percent.
	Nitrogen	Potash	Phos. Acid	Fertil- ized	Not Fertilized	
1	60	60	60	34.21	25.59	+33.7
2	60	60	90	27.75	26.18	+ 6.0
3	60	90	60	23.55	20.19	+16.6
4	90	60	60	29.18	21.42	+36.2
5	90	90	60	31.69	24.45	+29.6
6	90	60	90	33.70	19.87	+69.6
7	60	90	90	25.71	22.21	+15.7
8	90	90	90	32.02	27.89	+14.8
9	60	60	none	24.28	24.59	— 1.3

## SUCROSE IN JUICE. PERCENT.

PLAT No.	Fertilization, Lbs. per Acre			Plant Cane		Ratoons	
	Nitro-gen	Potash	Phos. Acid	Fertil-ized	Not Fertilized	Fertil-ized	Not Fertilized
1	60	60	60	18.24	18.77	18.95	18.87
2	60	60	90	18.43	19.01	19.22	18.65
3	60	90	60	18.65	19.04	19.15	18.80
4	90	60	60	18.25	19.33	19.10	18.87
5	90	90	60	18.81	18.95	19.57	18.72
6	90	60	90	18.17	19.00	19.40	19.00
7	60	90	90	18.94	19.09	19.32	19.10
8	90	90	90	18.95	18.55	19.30	19.15
9	60	60	none	19.20	18.82	19.35	18.72

## PURITY OF JUICE. PLANT AND RATOONS.

PLAT No.	Fertilization, Lbs. per Acre			Plant Cane		Ratoons	
	Nitro-gen	Potash	Phos. Acid	Fertil-ized	Not Fertilized	Fertil-ized	Not Fertilized
1	60	60	60	91.7	92.2	93.06	93.22
2	60	60	90	91.6	93.1	92.86	92.12
3	60	90	60	89.6	92.7	93.48	92.18
4	90	60	60	91.7	93.1	92.94	92.37
5	90	90	60	92.5	92.2	94.11	92.54
6	90	60	90	91.2	92.6	93.71	92.33
7	60	90	90	91.5	92.5	93.75	93.49
8	90	90	90	92.0	92.0	92.94	93.05
9	60	60	none	92.3	92.2	93.28	92.56

## AVAILABLE SUGAR PFR ACRE. TONS.

## PLANT AND RATOONS.

PLAT No.	Fertilization, Lbs. per Acre			Plant Cane		Ratoons	
	Nitro- gen	Potash	Phos. Acid	Fertil- ized	Not Fertilized	Fertil- ized	Not Fertilized
1	60	60	60	6.86	6.38	5.01	3.75
2	60	60	90	5.61	6.26	4.16	3.77
3	60	90	60	6.30	5.39	3.51	2.93
4	90	60	60	5.91	6.80	4.31	3.12
5	90	90	60	7.08	6.36	4.83	3.55
6	90	60	90	7.17	5.95	4.58	2.91
7	60	90	90	6.37	7.24	3.83	3.20
8	90	90	90	6.75	7.72	4.78	3.76
9	60	60	none	6.37	7.08	3.64	3.56

## GAIN OR LOSS IN AVAILABLE SUGAR FROM FERTILIZATION.

## PLANT AND RATOONS.

PLAT No.	Fertilization, Lbs. per Acre			Plant Cane		Ratoons	
	Nitro- gen	Potash	Phos. Acid	Tons	Percent.	Tons	Percent.
1	60	60	60	+ .48	+ 7.5	+ 1.26	+ 33.6
2	60	60	90	— .65	— 10.4	+ .39	+ 10.3
3	60	90	60	+ .91	+ 16.9	+ .58	+ 19.8
4	90	60	60	— .89	— 13.1	+ 1.19	+ 38.1
5	90	90	60	+ .72	+ 11.3	+ 1.28	+ 36.0
6	90	60	90	+ 1.22	+ 20.5	+ 1.67	+ 57.4
7	60	90	90	— .87	— 12.0	+ .54	+ 16.4
8	90	90	90	— .97	— 12.6	+ 1.02	+ 27.1
9	60	60	none	— .71	— 10.3	+ .08	+ 2.2

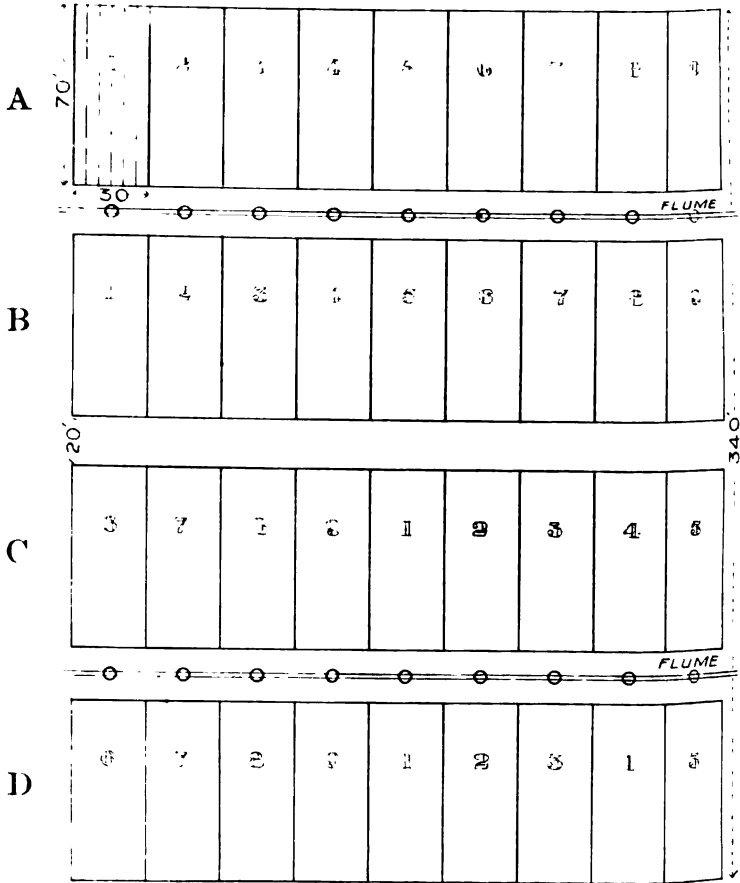
## GAIN OR LOSS IN AVAILABLE SUGAR FROM FERTILIZATION.

## AVERAGE OF PLANT AND RATOONS,

PLAT No.	Fertilization, Lbs. per Acre			Average Gain or Loss		Basis
	Nitrogen	Potash	Phos. Acid	Tons	Percent.	Tons
1	60	60	60	+ .87	+17.2	5.06
2	60	60	90	— .13	— 2.6	5.01
3	60	90	60	+ .74	+17.8	4.16
4	90	60	60	+ .15	+ 3.0	4.96
5	90	90	60	+1.00	+20.2	4.95
6	90	60	90	+1.44	+32.5	4.43
7	60	90	90	— .16	— 3.0	5.26
8	90	90	90	+ .02	+ .3	5.74
9	60	60	None	— .31	— 5.8	5.32

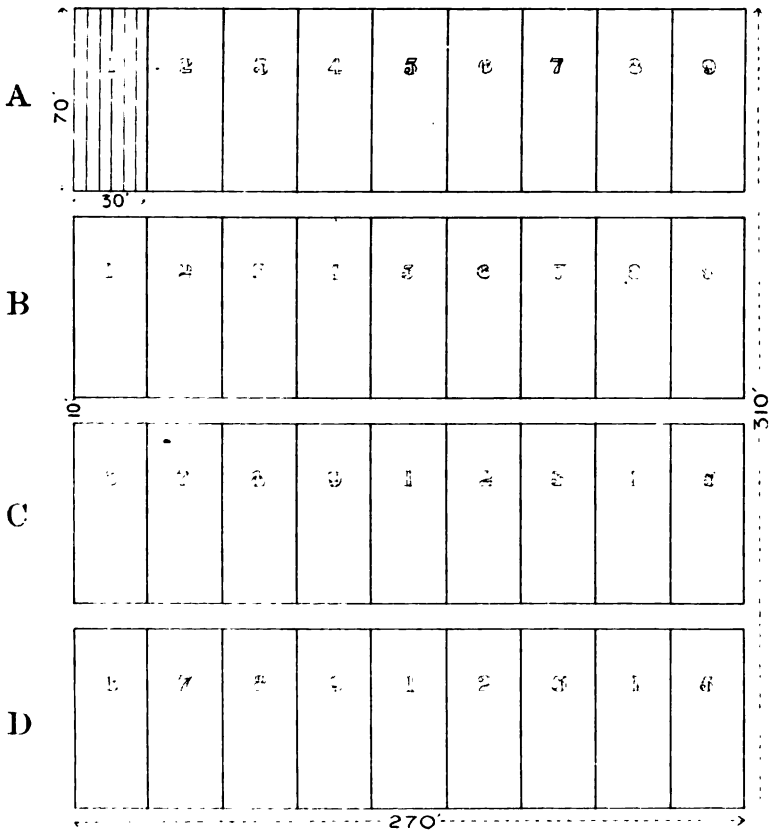
# SUBSTATIONS C AND D. (Elevation 700 feet).

DIAGRAM OF EXPERIMENT PLATS, SUBSTATION C.



Note.—This substation was laid out in such a manner that it could be irrigated by means of tanks and flumes as in the case of Substation A. A system of accurately measuring the water was not followed, however, for the ratoons, and the ordinary plantation method of irrigating was adopted. On this account comparisons with respect to the yields of different plats as influenced by fertilizer applications are precluded in this instance, except when made in a very general way.

DIAGRAM OF EXPERIMENT PLATS, SUBSTATION D.



## ANALYSIS OF SOIL OF SUBSTATION C AND D

The soil of these substations is a brown loam of about 14 inches depth underlaid by dark yellow subsoil to a depth of approximately three feet. The cosmopolitan of the top soil is indicated by the following analysis:

*Mechanical Analysis.*

Loss on ignition.....	31.71
Coarse grits .....	3.06
Fine grits .....	2.66
Coarse sand .....	.93
Medium sand .....	2.90
Fine sand .....	22.32
Coarse silt .....	16.82
Fine silt .....	18.30
Clay .....	2.09
Total.....	100.79

*Agricultural Analysis.*

Combined Moisture and Org Matter...	17.42
Insoluble residue .....	43.30
Iron oxide ( $\text{Fe}_2\text{O}_3$ ).....	17.03
Alumina ( $\text{Al}_2\text{O}_3$ ) .....	19.00
Manganese oxide ( $\text{Mn}_3\text{O}_4$ ).....	.21
Lime ( $\text{CaO}$ ) .....	.33
Potash ( $\text{K}_2\text{O}$ ) .....	.40
Soda ( $\text{Na}_2\text{O}$ ) .....	.30
Sulphuric anhydride .....	.14
Phosphoric anhydride .....	.84
Chlorine .....	.02
Total.....	99.48

Nitrogen .....	.391
Soluble silica .....	17.75
Humus .....	6.57
Nitrogen in humus.....	4.01
Absorptive power .....	34.00
Moisture in air dry soil.....	17.21
Reaction .....	Acid

*Aspartic Acid Analysis.*

Lime .....	.078
Potash .....	.011
Phosphoric acid .....	.0003
Nitrogen .....	.39
Moisture in air dry soil.....	18.16

*Slope of Field.*

The experiment area had a 5 percent grade running approximately at right angles to line of furrows and a 2 percent fall running with cane rows.

PLANT CANE TESTS AT SUBSTATIONS C AND D.

The data given below in regard to treatment of plats, and weather conditions, apply to both Substation C (irrigated) and Substation D (unirrigated), except when specified.

*Preparation of Land for Planting.*

May 5, 1905: steam plowed once to a depth of 16 inches.

May 6, 1905: harrowed with steam harrow.

May 27, 1905: plowed by gang disk plow, twice.

June 2, 1905: harrowed by mule harrow, twice.

June 6, 1905: cleared.

June 9, 1905: furrowed out with double mould-board plow.

*Planting.*

Plats were planted with Yellow Caledonia cane on the 15th and 16th of June, 1905.

*Treatment of Plats.*

Some replanting was performed on August 2, 1905, and fertilizer was applied on August 3, 1905, and April 5, 1906.

In the case of Substation C, six applications of water were given the plats, the dates of watering being as follows: June 23rd and 30th, and July 7th, 14th, 21st, and 28th; in each instance two inches of water were applied.



*Weather Conditions.*

The following temperature and rainfall record, at 270 feet elevation, affords an idea of the weather conditions prevailing at Substations C and D during the period under consideration, viz.: June 15, 1905, to May 21, 1907.

TEMPERATURE AND RAINFALL RECORD.

MONTH	Temperature			Rainfall
	Max.	Min.	Mean	
June, 1905.....	85	60	73.3	2.17
July .....	84	62	74.3	3.21
Aug. ....	84	67	75.6	6.35
Sept. ....	84	65	74.8	7.38
Oct. ....	85	63	73.8	4.01
Nov. ....	86	61	72.4	4.52
Dec. ....	83	60	70.6	6.08
Jan., 1906.....	84	59	70.8	4.65
Feb. ....	84	55	70.3	1.88
Mar. ....	84	58	69.9	3.30
April .....	85	55	71.2	8.36
May .....	85	55	71.2	14.66
June .....	83	64	74.2	1.97
July .....	84	66	74.2	7.77
Aug. ....	83	60	74.4	6.38
Sept. ....	88	66	76.4	3.22
Oct. ....	88	65	75.8	2.22
Nov. ....	84	61	73.8	3.82
Dec. ....	84	60	70.8	14.96
Jan., 1907.....	83	59	71.6	2.74
Feb. ....	84	56	70.4	8.73
Mar. ....	82	58	69.2	5.20
April .....	80	60	69.7	3.79
May .....	88	62	73.8	1.49
Average.....	84.3	60.7	72.6	128.86 Total

*Harvesting of Plant Cane on the Experiment Plats.*

The cane on the test rows was cut and weighed, and the juice tested on the 20th and 21st of March, 1907.

*Statements of Cane Weights and Juice Analysis.*

SUBSTATION C. WEIGHTS OF PLANT CANE HARVESTED MARCH 20,  
AND 21, 1907.

PLAT	Area Cut Sq. Ft.	Wt. of Cane Lbs.	PLAT	Area Cut Sq. Ft.	Wt. of Cane Lbs.
A 1	700	1254	C 1	700	1215
A 2	"	1434	C 2	"	1149
A 3	"	1206	C 3	"	1021
A 4	"	1307	C 4	"	1420
A 5	"	1490	C 5	"	1279
A 6	"	1299	C 6	"	1508
A 7	"	1137	C 7	"	1470
A 8	"	1124	C 8	"	1343
A 9	"	1118	C 9	"	1077
E 1	"	843	D 1	"	928
P 2	"	1046	D 2	"	785
P 3	"	943	D 3	"	615
B 4	"	1021	D 4	"	729
B 5	"	1247	D 5	"	690
B 6	"	1059	D 6	"	708
E 7	"	983	D 7	"	836
B 8	"	919	D 8	"	729
B 9	"	904	D 9	"	867

The areas and cane weights given above are correct.

Signed, E. G. CLARKE,

For Experiment Station, H. S. P. A.

## SUBSTATION D. WEIGHTS OF PLANT CANE.

PLAT	Area Cut Sq. Ft.	Wt. of Cane Lbs.	PLAT	Area Cut Sq. Ft.	Wt. of Cane Lbs.
A 1	700	1108	C 1	700	1265
A 2	"	1221	C 2	"	1072
A 3	"	1084	C 3	"	959
A 4	"	1241	C 4	"	1294
A 5	"	1523	C 5	"	1170
A 6	"	1407	C 6	"	1308
A 7	"	1462	C 7	"	1174
A 8	"	1377	C 8	"	1178
A 9	"	1277	C 9	"	1195
B 1	"	1060	D 1	"	906
B 2	"	942	D 2	"	893
B 3	"	903	D 3	"	847
B 4	"	1069	D 4	"	965
B 5	"	875	D 5	"	849
B 6	"	780	D 6	"	806
B 7	"	741	D 7	"	556
B 8	"	1070	D 8	"	601
B 9	"	1074	D 9	"	605

The areas and cane weights given above are correct.

Signed, E. G. CLARKE.

For Experiment Station, H. S. P. A.

## SUBSTATION C. ANALYSIS OF JUICE FROM PLANT CANE.

Plat	Brix	Sucrose	Purity	Plat	Brix	Sucrose	Purity
A 1	21.48	19.31	89.90	C 1	22.41	20.50	91.48
A 2	21.52	19.29	89.64	C 2	21.91	19.80	90.37
A 3	20.18	17.95	88.94	C 3	22.31	20.20	90.54
A 4	21.28	19.25	90.46	C 4	21.92	19.95	91.01
A 5	21.58	19.48	90.27	C 5	21.92	19.84	90.51
A 6	21.58	19.66	91.10	C 6	22.35	20.09	89.89
A 7	21.21	19.12	90.14	C 7	21.65	19.64	90.72
A 8	21.58	19.44	90.08	C 8	21.95	19.91	90.71
A 9	21.01	19.43	92.48	C 9	22.12	19.98	90.33
B 1	22.12	19.70	89.06	D 1	22.02	19.91	90.42
B 2	21.95	19.65	89.52	D 2	21.85	19.95	91.30
B 2	21.88	19.65	89.81	D 3	21.52	19.35	89.91
B 4	21.72	19.58	90.15	D 4	21.85	19.74	90.34
B 5	21.82	19.84	90.92	D 5	21.92	19.74	90.05
B 6	21.72	19.79	91.12	D 6	22.21	19.80	89.14
B 7	20.65	18.15	87.89	D 7	22.61	20.40	90.23
B 8	21.92	19.97	91.10	D 8	22.25	19.91	89.48
B 9	21.32	18.77	88.04	D 9	21.72	19.66	90.52

Fiber % Cane (approximate)=12.86.

Signed, S. S. PECK.

Assistant Chemist, Experiment Station, H. S. P. A.

## SUBSTATION D. ANALYSIS OF JUICE FROM PLANT CANE.

Plat	Brix	Sucrose	Purity	Plat	Brix	Sucrose	Purity
A 1	21.94	19.60	89.33	C 1	22.09	20.20	91.44
A 2	22.08	19.70	89.21	C 2	21.65	19.75	91.22
A 3	21.91	19.75	90.14	C 3	22.12	20.05	90.64
A 4	22.14	19.90	89.88	C 4	22.12	20.15	91.09
A 5	21.98	19.60	89.17	C 5	21.95	19.80	90.21
A 6	22.41	20.30	90.58	C 6	21.72	19.75	90.93
A 7	22.88	20.45	89.38	C 7	22.15	20.35	91.87
A 8	21.58	19.15	88.74	C 8	21.99	20.05	91.18
A 9	21.91	19.70	89.91	C 9	22.22	20.30	91.36
B 1	21.94	19.25	87.74	D 1	21.68	19.40	89.48
B 2	21.34	19.05	89.27	D 2	21.18	19.05	89.94
B 3	22.04	19.50	88.47	D 3	21.58	19.65	91.06
B 4	21.91	19.70	89.91	D 4	21.65	19.75	91.22
B 5	21.52	19.50	90.61	D 5	21.31	19.45	91.27
B 6	21.52	19.50	90.61	D 6	21.65	19.60	90.53
B 7	22.15	19.90	89.84	D 7	21.68	19.35	89.25
B 8	21.45	19.60	91.37	D 8	21.55	19.50	90.48
B 9	21.79	19.90	91.33	D 9	21.75	19.70	90.57

Fiber % Cane (approximate)=12.86.

Signed, S. S. PECK.

Assistant Chemist, Experiment Station, H. S. P. A.

# RATOON CANE TESTS AT SUBSTATIONS C AND D.

## *Cutting Back*

The plats were all cut back on July 6 and 8, 1907.

## *Treatment of Plats at Both Substations.*

First hoeing, August 8, 10, 12, 1907.

First application of fertilizer, August 15, 1907.

Cultivated with small plows, August 29, 30, 31, and September 2, 1907.

Cultivated with small cultivators, October 8 and 9, 1907.

Second hoeing, October 10 and 11, 1907.

Cultivated with small plows, October 12, 14, 15 and 16, 1907.

Furrows hilled with double disk plow, October 22, 1907.

Third hoeing December 30, 1907.

Hoed February 18, 1908, and second application of fertilizer made February 19, 1908.

Stripped December 29, 1908.

## *Irrigation of Substation C.*

The dates of watering by the plantation method were as follows: November 18 and December 28, 1907; January 22, February 3 and 15, March 3 and 17, April 1 and 16, May 1 and 15, and June 2, 1908. After June 2, 1908, the irrigation was discontinued, as the rainfall was considered sufficient. The quantities of water applied to the ratoons are not known.

*Weather Conditions.*

The temperature and rainfall record at 270 feet elevation, and rainfall record at 960 feet elevation, afford an idea of the prevailing weather conditions during the growth of the ratoons.

## TEMPERATURE AND RAINFALL,

MONTH	Temperature			Rainfall	
	Max.	Min.	Mean	Elev. 270 ft.	Elev. 960 ft.
July, 1907.....	81.58	68.42	75.00	4.28	....
Aug. ....	80.29	69.51	74.90	8.37	....
Sept. ....	82.00	69.40	75.70	7.85	....
Oct. ....	80.70	67.20	73.95	4.75	....
Nov. ....	79.10	65.60	72.40	6.00	....
Dec. ....	78.26	65.00	71.62	1.81	....
Jan., 1908.....	76.84	62.35	69.60	2.10	....
Feb. ....	76.76	61.97	69.36	3.25	....
March ....	79.30	63.50	71.40	1.91	....
April ....	76.90	63.80	70.30	3.24	3.50
May ....	78.20	65.60	71.90	5.23	5.16
June ....	78.33	65.70	72.01	5.59	5.25
July ....	78.60	66.50	72.60	7.71	9.55
Aug. ....	79.70	67.40	73.60	6.31	8.41
Sept. ....	80.01	67.23	73.70	5.70	6.75
Oct. ....	79.10	66.50	72.80	3.18	3.10
Nov. ....	79.00	63.70	71.40	3.71	3.80
Dec. ....	74.70	62.90	68.80	7.17	11.39
Jan., 1909.....	76.50	61.30	68.90	3.65	4.11
Feb. ....	75.50	60.50	68.00	6.01	7.36
Average....	78.60	65.2	71.9	97.82 (Total)	

*Harvesting of Ratoon Cane on the Experiment Plats.*

The cane on the middle two rows of each plat was cut and weighed and the juice tested March 15 and 16, 1909.

## STATEMENTS OF CANE WEIGHTS AND JUICE ANALYSIS.

## SUBSTATION C. WEIGHTS OF RATOON CANE.

Plat	Fertilized Test Area	Weight of Cane Lbs.	No. of Dead Canes	Plat	Unfertilized Test Area	Weight of Cane Lbs.	No. of Dead Canes
A 1	700 sq. ft.	823	1	B 1	700 sq. ft.	544	0
A 2	" "	915	0	B 2	" "	630	0
A 3	" "	739	2	B 3	" "	608	1
A 4	" "	1074	1	B 4	" "	653	0
A 5	" "	1230	2	B 5	" "	721	3
A 6	" "	1178	3	B 6	" "	734	0
A 7	" "	774	3	B 7	" "	517	0
A 8	" "	986	1	B 8	" "	392	2
A 9	" "	1228	3	B 9	" "	671	1
C 6	" "	1023	2	D 6	" "	626	3
C 7	" "	981	1	D 7	" "	607	2
C 8	" "	1000	2	D 8	" "	536	3
C 9	" "	680	3	D 9	" "	535	5
C 1	" "	770	1	D 1	" "	537	2
C 2	" "	803	3	D 2	" "	535	2
C 3	" "	613	2	D 3	" "	403	1
C 4	" "	872	2	D 4	" "	427	1
C 5	" "	1288	1	D 5	" "	524	6

The areas and cane weights given above are correct.

Signed, E. G. CLARKE,  
For Experiment Station, H. S. P. A.



## SUBSTATION D. WEIGHTS OF RATOON CANE.

Plot	Fertilized Test Area	Weight of Cane Lbs.	No. of Dead Canes	Plot	Unfertilized Test Area	Weight of Cane Lbs.	No. of Dead Canes
A 1	700 sq. ft.	805	3	B 1	700 sq. ft.	761	3
A 2	" "	612	2	B 2	" "	586	3
A 3	" "	553	6	B 3	" "	495	2
A 4	" "	601	7	B 4	" "	588	9
A 5	" "	764	7	B 5	" "	511	6
A 6	" "	910	8	B 6	" "	431	2
A 7	" "	823	4	B 7	" "	456	3
A 8	" "	862	8	B 8	" "	503	5
A 9	" "	666	2	B 9	" "	557	5
C 6	" "	1021	0	D 6	" "	686	3
C 7	" "	736	2	D 7	" "	448	2
C 8	" "	586	6	D 8	" "	429	1
C 9	" "	591	2	D 9	" "	538	3
C 1	" "	630	1	D 1	" "	713	2
C 2	" "	526	5	D 2	" "	588	4
C 3	" "	526	4	D 3	" "	695	4
C 4	" "	723	2	D 4	" "	514	3
C 5	" "	844	5	D 5	" "	558	2

The areas and cane weights given above are correct.

Signed, E. G. CLARKE,

For Experiment Station, H. S. P. A.

## SUBSTATION C. ANALYSIS OF JUICE FROM RATON CANE.

Plat	Brix	Sucrose	Purity	Plat	Brix	Sucrose	Purity
A 1	19.17	17.60	91.81	B 1	18.93	17.25	91.12
A 2	19.53	17.90	91.65	B 2	19.53	17.85	91.40
A 3	19.57	17.95	91.72	B 3	19.43	17.55	90.32
A 4	19.23	17.75	92.30	B 4	19.33	17.70	91.55
A 5	19.63	18.30	93.22	B 5	19.83	18.25	92.03
A 6	19.63	18.05	91.95	B 6	19.60	18.15	92.60
A 7	19.53	17.90	91.65	B 7	19.70	18.00	91.37
A 8	19.73	18.10	91.23	B 8	19.40	17.65	90.98
A 9	19.83	18.60	93.80	B 9	19.97	18.20	91.14
C 6	19.80	18.25	92.17	D 6	19.97	18.35	91.89
C 7	19.20	17.55	91.41	D 7	19.97	18.45	92.39
C 8	19.33	17.75	91.83	B 8	19.50	18.00	92.31
C 9	19.03	17.15	90.12	D 9	20.00	18.15	90.75
C 1	19.73	18.00	91.23	D 1	19.77	18.05	91.30
C 2	19.83	18.30	92.28	D 2	19.87	18.05	90.85
C 3	19.83	18.30	92.28	D 3	19.67	17.85	90.75
C 4	19.63	18.25	92.98	D 4	19.47	17.80	91.42
C 5	20.00	18.20	91.00	D 5	19.70	18.00	91.37

Signed, A. E. JORDAN,

Assistant Chemist, Experiment Station, H. S. P. A.

## SUBSTATION D. ANALYSIS OF JUICE FROM RATOON CANE.

Flat	Brix	Sucrose	Purity	Flat	Brix	Sucrose	Purity
A 1	19.06	17.20	90.24	B 1	19.43	17.35	89.30
A 2	19.16	17.15	89.51	B 2	19.73	17.70	89.71
A 3	19.26	17.20	89.30	B 3	19.93	17.75	89.06
A 4	19.86	17.85	89.88	B 4	19.93	17.85	89.56
A 5	19.56	18.00	92.02	B 5	19.40	17.00	87.63
A 6	19.76	17.90	90.58	B 6	18.90	16.90	89.42
A 7	20.06	18.05	89.98	B 7	19.40	17.35	89.43
A 8	20.13	18.10	89.92	B 8	19.80	17.65	89.14
A 9	19.73	17.75	89.96	B 9	19.90	17.60	88.44
C 6	20.50	18.60	90.73	D 6	19.93	17.95	90.07
C 7	19.90	18.10	90.96	D 7	19.13	17.20	89.91
C 8	20.40	18.75	91.91	D 8	19.83	17.90	90.27
C 9	19.90	18.40	92.46	D 9	19.83	18.10	91.28
C 1	19.90	18.05	90.70	D 1	19.46	17.65	90.70
C 2	19.70	17.85	90.61	D 2	19.96	18.10	90.68
C 3	19.60	17.85	91.07	D 3	20.06	18.10	90.23
C 4	19.80	17.90	90.40	D 4	19.83	18.40	92.78
C 5	20.20	18.35	90.84	D 5	19.83	18.20	91.78

Signed, A. E. JORDAN.

Assistant Chemist, Experiment Station, H. S. P. A.

## DATA FROM TESTS CONDUCTED AT SUBSTATION C.

## YIELDS OF CANE ON THE FERTILIZED AND UNFERTILIZED PLATS.

## PLANT CANE.

Plat No.	Fertilization, Lbs. per Acre			Area Cut Square Feet	Weight of Cane, Lbs.	
	Nitrogen	Potash	Phos. Acid		Fertil- ized	Not Fertil- ized
1	60	60	60	1400	2469	1771
2	60	60	90	"	2583	1831
3	60	90	60	"	2227	1558
4	90	60	60	"	2727	1750
5	90	90	60	"	2769	1937
6	90	60	90	"	2807	1767
7	60	90	90	"	2607	1819
8	90	90	90	"	2467	1648
9	60	60	None	"	2195	1771

## RATOONS.

Plat No.	Fertilization, Lbs. per Acre			Area Cut Square Feet	Weight of Cane, Lbs.	
	Nitrogen	Potash	Phos. Acid		Fertil- ized	Not Fertil- ized
1	60	60	60	1400	1593	1081
2	60	60	90	"	1718	1165
3	60	90	60	"	1352	1011
4	90	60	60	"	1946	1080
5	90	90	60	"	2518	1245
6	90	60	90	"	2201	1360
7	60	90	90	"	1755	1124
8	90	90	90	"	1986	1128
9	60	60	None	"	1908	1206

## YIELDS OF PLANT CANE PER ACRE.

Plat No.	Fertilization. Lbs. per Acre.			Cane per Acre. Tons		Gain from Fertilization Percent.
	Nitrogen	Potash	Phos. Acid	Fertilized	Not Fertilized	
1	60	60	60	38.41	27.55	39.4
2	60	60	90	40.18	28.48	41.1
3	60	90	60	34.65	24.24	42.9
4	90	60	60	42.42	27.22	55.8
5	90	90	60	43.08	30.13	43.0
6	90	60	90	43.67	27.49	58.9
7	60	90	90	40.56	28.30	43.3
8	90	90	90	38.38	25.64	49.7
9	60	60	None	34.15	27.55	24.0

## YIELDS OF RATOONS PER ACRE.

Plat No.	Fertilization. Lbs. per Acre.			Cane per Acre. Tons		Gain from Fertilization Percent.
	Nitrogen	Potash	Phos. Acid	Fertilized	Not Fertilized	
1	60	60	60	24.78	16.82	47.3
2	60	60	90	26.72	18.12	47.4
3	60	90	60	21.03	15.73	33.7
4	90	60	60	30.27	16.80	80.0
5	90	90	60	39.17	19.36	102.3
6	90	60	90	34.24	21.16	61.8
7	60	90	90	27.30	17.48	56.2
8	90	90	90	30.89	20.50	50.7
9	60	60	None	29.68	18.76	58.2

## SUCROSE IN JUICE. PERCENT.

## PLANT AND RATOONS.

Plat No.	Fertilization, Lbs. per Acre			Plant Cane		Ratoons	
	Nitro-gen	Potash	Phos. Acid	Fertil-ized	Not Fertilized	Fertil-ized	Not Fertilized
1	60	60	60	19.90	19.80	17.80	17.65
2	60	60	90	19.54	19.80	18.10	17.95
3	60	90	60	19.07	19.50	18.12	17.70
4	90	60	60	19.60	19.66	18.00	17.75
5	90	90	60	19.66	19.79	18.25	18.12
6	90	60	90	19.87	19.79	18.15	18.25
7	60	90	90	19.38	19.27	17.72	18.22
8	90	90	90	19.67	19.94	17.92	17.82
9	60	60	None	19.70	19.21	17.87	18.17

## PURITY OF JUICE. PLANT AND RATOONS.

Plat No.	Fertilization, Lbs. per Acre			Plant Cane		Ratoons	
	Nitro-gen	Potash	Phos. Acid	Fertil-ized	Not Fertilized	Fertil-ized	Not Fertilized
1	60	60	60	90.7	89.7	91.52	91.21
2	60	60	90	90.0	90.4	91.96	91.12
3	60	90	60	89.8	89.9	92.00	90.53
4	90	60	60	90.7	90.3	92.64	91.48
5	90	90	60	90.4	90.5	92.11	91.70
6	90	60	90	90.5	90.1	92.06	92.24
7	60	90	90	90.4	89.1	91.53	91.88
8	90	90	90	90.4	90.3	91.53	91.64
9	60	60	None	91.4	89.3	91.96	90.94

## AVAILABLE SUGAR PER ACRE. TONS.

## PLANT AND RATOONS.

Plat No.	Fertilization, Lbs. per Acre			Plant Cane		Ratoons	
	Nitro- gen	Potash	Phos. Acid	fertil- ized	Not Fertilized	Fertil- ized	Not Fertilized
1	60	60	60	5.88	4.16	3.27	2.28
2	60	60	90	5.99	4.25	3.73	2.49
3	60	90	60	5.00	3.61	2.93	2.12
4	90	60	60	6.36	4.09	4.20	2.29
5	90	90	60	6.47	4.56	5.51	2.70
6	90	60	90	6.68	4.15	4.79	2.98
7	60	90	90	6.02	4.12	3.71	2.46
8	90	90	90	5.78	3.91	4.26	2.75
9	60	60	None	5.18	4.03	4.15	2.61

## GAIN IN AVAILABLE SUGAR FROM FERTILIZATION.

## PLANT AND RATOONS.

Plat No.	Fertilization, Lbs. per Acre			Plant Cane		Ratoons	
	Nitrogen	Potash	Phos. Acid	Tons	Percent	Tons	Percent.
1	60	60	60	1.72	41.3	.99	43.4
2	60	60	90	1.74	40.9	1.24	49.8
3	60	90	60	1.39	38.5	.81	38.2
4	90	60	60	2.27	55.5	1.91	83.4
5	90	90	60	1.91	41.9	2.81	104.1
6	90	60	90	2.53	60.9	1.81	60.7
7	60	90	90	1.90	46.1	1.25	50.8
8	90	90	90	1.87	47.8	1.51	54.9
9	60	60	None	1.15	28.5	1.54	59.0

## GAIN IN AVAILABLE SUGAR FROM FERTILIZATION.

## AVERAGE OF PLANT AND RATOONS.

Plat No.	Fertilization. Lbs. per Acre			Average Gain		Basis
	Nitrogen	Potash	Phos. Acid	Tons	Percent.	Tons
1	60	60	60	1.35	41.9	3.22
2	60	60	90	1.49	44.2	3.37
3	60	90	60	1.10	38.5	2.86
4	90	60	60	2.09	65.5	3.19
5	90	90	60	2.36	65.0	3.63
6	90	60	90	2.17	61.0	3.56
7	60	90	90	1.57	47.7	3.29
8	90	90	90	1.69	50.8	3.33
9	60	60	None	1.34	40.4	3.32



## DATA FROM TESTS CONDUCTED AT SUBSTATION D.

## YIELDS OF CANE ON THE FERTILIZED AND UNFERTILIZED PLATS.

## PLANT CANE,

Plat No.	Fertilization. Lbs. per Acre			Area Cut Square Feet	Weight of Cane. Pounds	
	Nitrogen	Potash	Phos. Acid		Fertilized	Not Fertilized
1	60	60	60	1400	2373	2056
2	60	60	90	"	2293	1835
3	60	90	60	"	2043	1750
4	90	60	60	"	2535	2034
5	90	90	60	"	2693	1724
6	90	60	90	"	2715	1586
7	60	90	90	"	2636	1297
8	90	90	90	"	2555	1671
9	60	60	None	"	2472	1679

## RATOONS.

Plat No.	Fertilization. Lbs. per Acre			Area Cut Square Feet	Weight of Cane. Pounds	
	Nitrogen	Potash	Phos. Acid		Fertilized	Not Fertilized
1	60	60	60	1400	1435	1474
2	60	60	90	"	1138	1174
3	60	90	60	"	1079	1190
4	90	60	60	"	1384	1102
5	90	90	60	"	1608	1069
6	90	60	90	"	1931	1117
7	60	90	90	"	1559	904
8	90	90	90	"	1448	932
9	60	60	None	"	1257	1095

## YIELDS OF PLANT CANE PER ACRE.

Plat No.	Fertilization. Lbs. per Acre			Cane per Acre. Tons		Gain from Fertilization Percent.
	Nitrogen	Potash	Phos. Acid	Fertilized	Not Fertilized	
1	60	60	60	36.92	31.99	15.4
2	60	60	90	35.67	28.55	24.2
3	60	90	60	31.78	27.22	16.8
4	90	60	60	39.44	36.64	7.6
5	90	90	60	41.90	26.82	56.2
6	90	60	90	42.24	24.67	71.2
7	60	90	90	41.01	20.18	103.2
8	90	90	90	39.75	26.00	52.7
9	60	60	None	38.46	26.12	47.2

## YIELDS OF RATOONS PER ACRE.

Plat No.	Fertilization. Lbs. per Acre			Cane per Acre. Tons		Gain or Loss from Fertilization. Percent.
	Nitrogen	Potash	Phos. Acid	Fertilized	Not Fertilized	
1	60	60	60	22.32	22.92	— 2.6
2	60	60	90	17.70	18.26	— 3.1
3	60	90	60	16.78	18.51	— 9.3
4	90	60	60	21.53	17.14	+25.6
5	90	90	60	25.01	16.63	+50.4
6	90	60	90	30.04	17.37	+72.9
7	60	90	90	24.25	14.06	+72.5
8	90	90	90	22.52	14.50	+55.3
9	60	60	None	19.50	17.03	+14.5

## SUCROSE IN JUICE. PERCENT.

## PLANT AND RATOONS.

Plat No.	Fertilization Lbs per Acre			Plant Cane		Ratoons	
	Nitro-gen	Potash	Phos. Acid	Fertil-ized	Not Fertilized	Fertil-ized	Not Fertilized
1	60	60	60	19.90	19.32	17.62	17.50
2	60	60	90	19.72	19.05	17.50	17.90
3	60	90	60	19.90	19.57	17.52	17.92
4	90	60	60	20.02	19.72	17.87	18.12
5	90	90	60	19.70	19.47	18.17	17.60
6	90	60	90	20.02	19.55	18.25	17.42
7	60	90	90	20.40	19.62	18.07	17.27
8	90	90	90	19.60	19.55	18.42	17.77
9	60	60	None	20.00	19.80	18.07	17.85

## PURITY OF JUICE. PLANT AND RATOONS.

Plat No.	Fertilization, Lbs. per Acre			Plant Cane		Ratoons	
	Nitro-gen	Potash	Phos. Acid	Fertil-ized	Not Fertilized	Fertil-ized	Not Fertilized
1	60	60	60	90.4	88.6	90.47	90.00
2	60	60	90	90.2	89.6	90.06	90.19
3	60	90	60	90.4	89.7	90.18	89.64
4	90	60	60	90.5	90.5	90.14	91.17
5	90	90	60	89.7	90.9	91.43	89.70
6	90	60	90	90.8	90.6	90.65	89.74
7	60	90	90	90.6	89.5	90.47	89.67
8	90	90	90	90.0	90.9	90.91	89.70
9	60	60	None	90.7	91.0	91.21	89.86

## AVAILABLE SUGAR PER ACRE. TONS.

## PLANT AND RATOONS.

Plat No.	Fertilization. Lbs. per Acre			Plant Cane		Ratoons	
	Nitro-gen	Potash	Phos. Acid	Fertilized	Not Fertilized	Fertilized	Not Fertilized
1	60	60	60	5.63	4.67	3.00	3.05
2	60	60	90	5.38	4.14	2.35	2.49
3	60	90	60	4.82	4.06	2.24	2.53
4	90	60	60	6.04	4.77	2.94	2.38
5	90	90	60	6.30	4.00	3.49	2.24
6	90	60	90	6.48	3.69	4.20	2.32
7	60	90	90	6.40	3.02	3.35	1.85
8	90	90	90	5.91	3.90	3.17	1.96
9	60	60	None	5.90	3.98	2.71	2.32

## GAIN OR LOSS IN AVAILABLE SUGAR FROM FERTILIZATION.

## PLANT AND RATOONS.

Plat No.	Fertilization. Lbs. per Acre			Plant Cane		Ratoons	
	Nitro-gen	Potash	Phos. Acid	Tons	Percent.	Tons	Percent.
1	60	60	60	+ .96	+ 20.5	— .05	— 1.6
2	60	60	90	+ 1.24	+ 29.9	— .14	— 5.6
3	60	90	60	+ .76	+ 18.7	— .29	— 11.4
4	90	60	60	+ 1.27	+ 26.6	+ .56	+ 23.5
5	90	90	60	+ 2.30	+ 57.5	+ 1.25	+ 55.8
6	90	60	90	+ 2.79	+ 75.6	+ 1.88	+ 81.0
7	60	90	90	+ 3.38	+ 111.9	+ 1.50	+ 81.1
8	90	90	90	+ 2.01	+ 51.5	+ 1.21	+ 61.7
9	60	60	None	+ 1.92	+ 48.2	+ .39	+ 16.8

## GAIN IN AVAILABLE SUGAR FROM FERTILIZATION.

## AVERAGE OF PLANT AND RATOONS,

Plat No.	Fertilization. Lbs. per Acre			Average Gain		Basis
	Nitrogen	Potash	Phos. Acid	Tons	Percent.	Tons
1	60	60	60	0.45	11.6	3.86
2	60	60	90	0.55	16.6	3.31
3	60	90	60	0.23	7.0	3.29
4	90	60	60	0.91	25.5	3.57
5	90	90	60	1.77	56.7	3.12
6	90	60	90	2.33	77.7	3.00
7	60	90	90	2.44	100.4	2.43
8	90	90	90	1.61	54.9	2.93
9	60	60	None	1.15	36.5	3.15





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AGRICULTURAL AND CHEMICAL SERIES

BULLETIN No. 30

REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION



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The Influence of the Structure of the Cane  
on Mill Work in Sugar Factories.

---

BY NOËL DEERR

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HONOLULU, HAWAII  
1910



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**REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
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**The Influence of the Structure of the Cane  
on Mill Work in Sugar Factories.**

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**BY NOËL DEERR**

---

**HONOLULU, HAWAII  
1910**



*See Facsimile*

## LETTER OF TRANSMITTAL.

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To the Experiment Station Committee of the Hawaiian Sugar  
Planters' Association, Honolulu, T. H.

Dear Sirs:

I herewith submit for publication as Bulletin No. 30 of the  
Agricultural and Chemical Series, an article by Mr. Noël Deerr,  
Sugar Technologist, entitled: "The Influence of the Structure of  
the Cane on Mill Work in Sugar Factories."

Yours very truly,

C. F. ECKART,  
Director.

Honolulu, Hawaii, December 23, 1909.



# THE INFLUENCE OF THE STRUCTURE OF THE CANE ON MILL WORK IN SUGAR FACTORIES.

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BY NOËL DEERR.

## INTRODUCTION.

The material presented in the present bulletin mainly contains a record of experimental work dealing chiefly with the influence of the structure of the cane on control, and on the extraction of sugar from the cane.

The bulletin is divided into three parts: in the first, the influence of the different juices contained in the cane on control work, is discussed; the second part contains an account of some experiments made with the object of determining the effect of different methods, and introduces the idea of the "*available*" as opposed to the actual extraction; in the third part, the cane is considered as composed of pith and rind, and the result of milling operations is considered on these portions as separate entities.

## PART I.

### ON ANALYTICAL CONTROLS OF CANE WEIGHTS.

Provided that all products of the sugar factory from the cane onwards could be *accurately* weighed, no necessity would exist for the use of inferential methods for their control; however, it is often the case that one or other of the measurements relating to the control cannot be, or is not, made, so that an element of uncertainty is introduced into the recorded results. In addition, even if all the products are weighed or measured, there is the possibility of error in the adjustment of the balances, so that the necessity of some check is always present.

An inferential check on the weight of cane is very important in districts where the cane is bought from small planters, or where its weight forms a basis of payment for contract laborers, as is the case locally.

*Previous Work.*—The first recorded inferential method of controlling the weight of cane is, I believe, due to Prinsen Geerligs, and has found a wide and extended application in Java. It is most frequently referred to as the .85 factor, and, expressed in words, means that on an average, under certain fixed conditions, the relation

$$\frac{\text{Sucrose \% in cane}}{\text{Sucrose \% in first mill juice}} = .85,$$

holds. It is at once apparent that this relation can only hold under constant conditions and for one definite mill pressure, and one definite percentage of fiber in the cane. As the amount of juice expressed increases, and at the same time more nearly represents in composition that of the absolute juice,\* the factor tends to increase. At the same time, with an increase in fiber and a decrease in the amount of the juice in the cane, the factor tends to fall. This point has been recognized from the inception of the formula in Java, Prinsen-Geerligs<sup>1</sup> having arranged the following table as showing the influence of fiber and mill pressure on the factor:

Juice per 100 cane	Fibre per 100 Cane.						
	9.5	10.0	10.5	11.0	11.5	12.0	12.5
65	84.60	84.40	84.20	84.00	83.85	83.75	83.65
66	84.75	84.60	84.45	84.30	84.15	84.05	83.95
67	85.05	84.90	84.75	84.60	84.45	84.35	84.25
68	85.40	85.20	85.05	84.90	84.75	84.60	84.45
69	85.70	85.50	85.35	85.20	85.05	84.90	84.75
70	85.95	85.70	85.60	85.50	85.35	85.20	85.05
71	86.15	86.00	85.90	85.80	85.85	85.50	85.35
72	86.45	86.30	86.20	86.10	85.95	85.80	85.65
73	86.70	86.55	86.30	86.40	86.25	86.10	85.95

As this table was constructed when the Cheribon † cane formed the staple variety grown in Java, it must be taken as referring solely to this variety, and it does not by any means follow that similar figures will hold for other varieties, or even when the environment of the variety is changed.

Assuming, however, that a similar condition holds for local grown canes which contain on an average 12.5% of fibre, the

\* By this term I mean all the juice contained in the cane. The term *whole juice* would be more convenient, but this has been used in a somewhat different sense by Watts whose work is referred to later.

† For synonyms of this cane refer to Bulletin No. 26.

factor .85 would be reached only when 70% of the weight of the cane is expressed by the mill. This is a higher figure than is usually the case here, and especially so when crusher juice is substituted for mill juice, as is frequently the case; hence, from a *prima facie* reasoning, so high a factor as .85 should not be expected.

The statement published annually in Java showing "*Some figures relating to Java Sugar Mills*" for the crop of 1908, gives as an average sucrose per cent. in cane 12.30, fibre per cent. in cane 12.01, and sucrose per cent. in first mill juice 15.11. This would correspond with a factor of .814. In a number of cases a factor below .8 is recorded, and in some instances it sinks as low as .75. This low result is, I believe, to be ascribed to the substitution of new varieties for the Cheribon cane, the former containing a smaller proportion of parenchyma than the latter. It is to this, I take it, that Geerligs<sup>2</sup> refers.

"The strikingly low sugar-content of the bagasse from several of the recently cultivated varieties of cane, is due to the small proportion of parenchyma in these canes; in the bagasse, the parenchyma contains more water than do the vascular bundles or rind; consequently with a low proportion of parenchyma, the bagasse is drier and therefore poorer in sugar."

This factor has also been discussed by Pellet<sup>3</sup> who, in Egypt, uses the factor .87 to pass from the sucrose per cent. of juice obtained by treble crushing to the sucrose per cent. of cane. In the same article he quotes the factor .84 as being used in Mauritius.

It seemed a matter of some interest to determine the relation between sucrose in expressed juice and sucrose in cane in Hawaiian grown canes, especially as very varying factors are reported from mills in these islands, some of them being apparently outside the limits of variation due to the causes already cited.

The two chief varieties now grown in these islands, are the Lahaina and Yellow Caledonia, with smaller quantities of Rose Bamboo, D. 117 and the Tip canes. I, accordingly, made analyses as described below of Lahaina canes from Maui and Oahu, Yellow Caledonia canes from Oahu, Kauai and Hawaii, and of Rose Bamboo canes from Oahu. The method I used was as follows:

A single cane was split lengthways and one-half passed through a two manual three-roller mill. The juice and bagasse were collected and the latter weighed; the weight of juice being obtained by subtraction of the weight of bagasse from weight of cane. Immediately after weighing, the bagasse was placed in a "*Mason*" jar with well-fitting screw stopper, and carried to the laboratory.



Two portions were then rapidly weighed out, one for determination of water, and one for determination of solids and sugar. The latter was divided at leisure into small pieces, the original weight being used in calculations. The soluble matter was extracted in a Soxhlet apparatus using water as the solvent. The flask containing the solvent was boiled over a direct flame, the contents of the flask being protected from local overheating and consequent destruction of sugar by setting the flask on a thick piece of asbestos in which was cut a circular hole immediately over the flame. To obtain a neutral reaction in the boiling extract, a little chalk was added. Blank experiments showed that no detectable inversion of sucrose took place under these conditions. After complete extraction of the soluble matter, which took about five hours, the extract was cooled and made up to definite volume, generally about 320 c.c.; then 250 c.c. of the extract was removed and evaporated on the water bath to small bulk and made up to 50 c.c. The total solids in this concentrated extract were determined by the refractometer and calculated to a percentage on the weight of bagasse. The remainder of the extract was used for a direct polarimetric assay of the sugar, a 600 m.m. tube being employed. In this way I was able to work with small quantities of material and thus to rigidly control the accuracy of the samples, and at the same time to obtain readings of magnitude sufficient to eliminate large percentage errors in observation. The solubility of the calcium carbonate in the extract was found by direct experiment to be so low as not to appreciably affect the refractometer readings.

The juice was analyzed in the usual way, the total solids being determined by the refractometer, and the sugar by direct polarization, as the object of the determinations did not call for the use of double polarization.

In all, I made analyses of fifty-seven canes in this way, the average result of each series being detailed in the table below:

		Oahu.	Kauai.	Oahu.	Oahu.	Maui.	Hawaii.
		Rose Bamboo	Y. Cale- donia.	Lahaina.	Y. Cale- donia.	Lahaina.	Y. Cale- donia.
Cane	Weight.....	100.00	100.00	100.00	100.00	100.00	100.00
	Fibre %.....	12.53	13.54	12.38	13.45	10.43	13.72
	Juice %.....	87.47	86.46	87.62	86.55	89.57	86.28
	Solids %.....	15.05	18.21	15.75	15.50	21.05	18.50
	Sucrose %.....	13.51	15.01	13.52	13.37	18.39	16.16
Expressed Juice	Water %.....	73.75	71.45	71.87	71.05	68.52	66.78
	Weight.....	64.65	63.10	65.15	64.58	68.50	60.56
	Solids %.....	17.59	21.58	18.38	18.30	24.14	21.91
	Sucrose %.....	16.22	18.41	16.21	16.31	21.25	19.73
	Purity.....	92.21	85.31	88.03	89.12	88.03	90.05
Bagasse	Weight.....	35.35	36.90	34.85	35.42	31.50	39.44
	Solids %.....	10.60	12.42	10.86	10.37	14.27	13.21
	Sucrose %.....	8.56	9.20	8.50	8.00	12.13	10.63
	Fibre %.....	35.45	36.69	35.47	37.97	33.19	34.78
	Water %.....	53.95	49.58	53.67	51.66	52.44	52.01
Absolute Juice	Weight.....	87.47	86.46	87.62	86.55	89.57	86.28
	Solids %.....	17.20	21.06	17.97	17.91	23.50	21.42
	Sucrose %.....	15.51	17.36	15.43	15.44	20.53	18.61
	Purity.....	90.17	82.44	85.87	86.21	87.36	86.88
	Weight.....	22.82	23.36	22.47	21.97	21.07	25.72
Bagasse Juice	Solids %.....	16.42	19.62	16.84	17.00	21.36	20.17
	Sucrose %.....	13.26	14.53	13.16	12.89	18.15	16.29
	Purity.....	81.00	74.06	78.14	75.82	84.97	80.76
Sucrose in Cane		.833	.815	.834	.819	.865	.819
Sucrose in Expressed Juice							
Solids in Absolute Juice							
		.978	.976	.977	.979	.973	.977
Solids in Expressed Juice							

Reference to the results of the analyses brings out the following points:

1. With Lahaina cane, containing 10% to 11% of fibre and with an expression of 68% to 69%, a factor of .86 to .87 results.

2. With Lahaina and Rose Bamboo cane, containing 12% to 13% of fibre and with an expression of 64% to 66%, a factor of .83 to .84 results.

3. With Yellow Caledonia cane, containing 13% to 14% of fibre and with an expression of 60% to 65%, a factor of .81 to .82 results, i.e., judged on a basis of first mill juice, Yellow Caledonia cane is distinctly inferior to Lahaina or to Rose Bamboo.

4. The residual juice in Yellow Caledonia compared with that in Lahaina and Rose Bamboo, is of distinctly inferior quality, the expressed juice being used as a basis of comparison.

5. A very similar relation between expressed juice and sucrose per cent. in cane holds for Hawaiian canes as has been found to hold for the Cheribon cane.

*Use of This Ratio.*—The analyses recorded above indicate that the sucrose per cent. of the cane is controlled essentially by the sucrose content of the expressed juice, and this relation rationally used (i.e., taking into account the fibre in the cane, and the quantity of juice expressed), affords a ready means of checking and controlling the correctness of the cane weights, of the juice measurements, and of the analyses. In Java, also, the ratio .85, as referring to the Cheribon cane, was used as a means of obtaining the approximate weight of sucrose entering the factory until opportunity arrived to make a periodical balance of the actual amount of cane worked up.

In factories where the amount of sucrose in cane is obtained by working backwards from the sucrose in mixed juice and sucrose in bagasse, a low ratio will indicate one of two things: either the recorded weight of cane is too high or the measurement of the volume, or the weight of the juice is too low.

*Density of Juice of the Cane as a Control.*—The use of the density of the absolute juice of the cane, compared with that of the expressed juice as a means of controlling the accuracy of the various measurements, was suggested to me by Mr. C. F. Eckart. In order to use a scheme based on this conception, it became necessary to carefully examine any relation which might exist between the two. This was done, and the results obtained are discussed in the following lines.

That the density of the juice of the cane is not uniform, and that it decreases as successive fractions are expressed, is perfectly well known, although the variation in density is much less than in sugar content.

I have found the following references on this matter. Prinsen-Geerligs<sup>4</sup> assumes that the Brix of the "*normal juice*" (without definitely stating that this is so) is the same as that of the first expressed juice.

Morse<sup>5</sup> recommends that the Brix of the normal juice compared with that of the first mill juice be obtained by a dry crushing trial, and states that it is generally 3/10 of 1° Brix lower than the first mill juice. A similar method is prescribed by the Hawaiian Chemists' Association.

Watts<sup>6</sup> discusses the subject at some length, and adopts the term *whole juice* to include all the juice of the cane. It appears that he assumes (though he gives details of an experiment showing the reverse) that the Brix of the *whole juice* is the same as that of the first mill, and also that all the juice is of the same com-

position as that expressed. That part of his article dealing with this question is quoted below :

"After careful consideration, the following conventional manner of estimating the amount of juice has been adopted at Gunthorpe's. The amount of juice contained in the total diluted juice is calculated, on the assumption that the average juice expressed from the canes would have the specific gravity (or total solids) of the first mill juice, but would have the purity of the total diluted juice. The juice so found is referred to as 'whole' juice.\* The calculated composition of the first mill juice and the 'whole' juice at Gunthorpe's during the season 1907 was as follows :

	First Mill Juice per cent.	'Whole' Juice * per cent.
Sucrose**.....	18.51	17.96
Glucose.....	0.93	0.88
Non-Sugar.....	1.14	1.74
Total Solids.....	20.58	20.58
Glucose Ratio.....	5.05	4.88
Purity.....	89.09	87.03
(*Lb. per gallon.....)	2.002	1.942)

\* If desired, the figures so obtained may be used to convert the expression 1st mill juice per 100 parts of fibre into 'whole' juice per 100 parts of fibre by multiplying by  
sucrose in 1st mill juice

sucrose in 'whole' juice  
when we find, for example, that 80.4 parts of first mill juice per 100 parts of fibre, as obtained at Gunthorpe's in 1907, are equivalent to 82.9 parts of 'average' juice.

"This assumption of the idea of 'whole' juice appears to be a useful one and, although only an assumption, it is very close to the truth. It may be contended by some that the residual juice, as we approach the end of the crushing and as left in the megass, will have a lower specific gravity than that expressed in the earlier stages of crushing. It will have a lower sugar content and lower purity, the amount of total solids not falling off so rapidly as the sucrose, so that there is not likely to be a great difference in the specific gravity.

$$* \text{ Weight 'whole' juice } = \frac{\text{Weight diluted juice} \times \text{Brix 1st mill juice}^\dagger}{\text{Brix diluted juice}}$$

† This is expressed as it appears in the original; evidently a clerical error has occurred and the expression should be written  

$$\frac{\text{Weight diluted juice} \times \text{Brix diluted juice}}{\text{Brix 1st mill juice}}$$

"There appears to be but a small amount of information available in order to settle the question as to the specific gravity of the residual juice. Some years ago, the megass from a small Chatanooga mill was submitted to pressure in a hydraulic press. This mill expressed about 65 per cent. of the weight of the cane in the form of juice, and the hydraulic press (which was of considerable power) expressed a further quantity of about 6 per cent.\* The specific gravity of the mill juice and the press juice was noted amongst other points. On referring to these figures, it is found that the average specific gravity of fifty samples of mill juice was 1.07047, while the average specific gravity of the press juice was 1.06773—a difference of .0037. Now, as the mill juice was about ten times the quantity of the press juice, the lowering of the average specific gravity by the admixture of the residual (press) juice, would be almost negligible in ordinary factory calculations.

"This convention is here adopted and is recommended for use in making comparisons of the kind dealt with herein.

"It may be pointed out that attempts to ascertain the amount of juice by weighing the megass and deducting the weight from the weight of cane are futile, seeing that where maceration is employed the weight of the megass will be some 5 per cent. above the true weight in consequence of its retaining some maceration water.

"It may again be stated that comparisons of mill work on the basis of first mill juice retained in the megass, per 100 parts of fibre, are free from all these uncertainties; the only difficulty being that of obtaining representative samples of megass—a difficulty not very great in large factories but very great under the condition of the muscovado industry."

The term whole juice is very convenient, but as used by Watts, it is not what I have in mind, so I use the term absolute juice of the cane meaning by this every thing which is not left behind on extraction with water, and thus including protoplasm, the colloid water of Geerligs, and the water other than juice of Watts.

The experiment method of determining the density of the absolute juice of the cane has been given on page 7, and the results have been set out on page 9. From a study of these results (the average of fifty-seven analyses) the following statement can be made:

The ratio between the total solids per cent. of the absolute juice of the cane and that expressed by the first mill lies between .97

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\* See (1) Supplement to *Leeward Islands Gazette*, August 27, 1896, and (2) Report on the results obtained on the Experimental Fields at Skerrett's, Antigua, 1897.

and .98, and this ratio is the same for at least three varieties of cane with fibre content varying from 10% to 14%.

Having obtained this ratio, I now proceed to develop its application to the sugar house control as follows:

Let  $f$  be the fiber in the cane;  $m$  be the fiber in the bagasse;  $B_c$ ,  $B_j$ ,  $B_m$  be the degree Brix or total solids % in the absolute juice, mixed juice, and residual juice in bagasse, all expressed per unit weight.

Let the weight of canes be unity; and the weight of mixed juice be  $a$ ; then from well known equations the weight of bagasse is  $\frac{f}{m}$  and the weight of juice\* in the bagasse is  $\frac{f}{m} (1-m)$ . The

total weight of juice is then  $a + \frac{f}{m} (1-m)$ . The solids in the total weight of juice are

$$a B_j + \frac{f}{m} (1-m) B_m$$

and the total solids per unit of juice are

$$\frac{a B_j + \frac{f}{m} (1-m) B_m}{a + \frac{f}{m} (1-m)} = \frac{a B_j m + f (1-m) B_m}{a m + f (1-m)}$$

The water added per unit of juice in the cane is then

$$B_c = \frac{a B_j m + f (1-m) B_m}{a m + f (1-m)} = \frac{a B_c m + f B_c - f m B_c - a B_j m - f B_m + f m B_m}{a B_j m + f (1-m) B_m}$$

Let this expression be denoted by  $P$ , the weight of juice is  $1-f$ ; hence the total weight of added water is  $(1-f) P$ .

Hence from the equation

$$\begin{aligned} \text{Cane} + \text{water} &= \text{mixed juice} + \text{bagasse} \\ 1 + (1-f) P &= a + \frac{f}{m} \end{aligned}$$

A numerical example will make clear the application of this equation. The following analytical data (expressed per unity) were found:

\* That is to say dilute juice and not normal juice.

$B_c = .209$  (i. e., 20.9 Brix);  $f = .119$ ;  $m = .487$ ;  $B_j = .190$ ;  
 $B_m = .088$ ; hence  $\frac{f}{1} = .2443$ ; and  $1 - f = .881$ .

From these quantities  $P$  is found to be

$$\frac{.0092 a + .0074}{.0925 a + .0053}$$

$$\text{Whence } 1 + .881 \frac{.0092 a + .0074}{.0925 a + .0053} = a + .2443$$

Solving this equation,  $a$  is found to be .9087, that is to say, the weight of mixed juice is 90.87% per 100 cane.

Then from the relation

$$\begin{array}{rcl} \text{Canes} + \text{water} & = & \text{mixed juice} + \text{bagasse} \\ 1 + w & = & .9087 + .2443 \\ \text{or water} & = & .1530, \text{ i. e., the water added in maceration is } 15.30 \\ & & \text{per 100 cane.} \end{array}$$

Hence if the density of the absolute juice of the cane be known, then with analytical data only, all the essential measurements connected with mill control can be expressed in terms of cane; and if either the weight of cane, of bagasse, of mixed juice or added water be known, all the other quantities can be calculated.

I do not, however, suggest that an inferential method should in any way supplant the use of direct weighing or measurements, but rather suggest the use of this equation as a means of checking the accuracy and correctness. So far as this is concerned, I am of opinion that a valuable check is given by comparing the total solids per cent. in expressed juice with that of the absolute juice of the cane, and in the light of the determination here recorded, I think I am justified in saying that the ratio should lie close to the figure .977, and that any big variation from this indicates an error. To obtain this quantity, the total solids in the bagasse must be accurately determined. The method prescribed by the Hawaiian Chemists' Association, namely, of spindling the bagasse extract, introduces too great a percentage error of observation; and the method which I have tested and found satisfactory, is mainly that already described on page 8. I would suggest that this determination be made periodically on the accumulated samples of bagasse used for the determination of moisture which should be preserved in air-tight jars after drying. I have found those known as "*Mason jars*" quite satisfactory, and *dry* bagasse can be preserved in them for indefinite periods without change. A subsample of 20 grams or so of dry bagasse representing, say, a week's work, may then be extracted in a

Soxhlet apparatus, the extract concentrated to, say, 50 cc., and the total solids determined therein by the refractometer; an example of the method of calculation follows.

Average water per cent. in bagasse 47.0; 20 grams of dry bagasse afforded an extract which on concentration to 50 cc., gave a reading of 1.3364 at 28° C. in the refractometer equivalent to 3% of solids. The total solids per cent. in the dry bagasse\* are

$$\frac{50 \times 3.00 \times 1.047}{20} = 7.59\%$$

The total solids in the original bagasse containing 47% water are

$$7.59 \times \frac{100 - 47}{100} = 4.02.$$

and the total solids per cent. in residual juice are

$$\frac{100 \times 4.02}{47 + 4.02} = 7.88.$$

*The Effect of Fluming.*—Fluming is a process almost, if not entirely, confined to the Hawaiian Islands. Naturally, the points discussed above refer solely to road transported cane. Owing to the flume water carried in with the cane, the first expressed juice is diluted and the value of the expressions

Sucrose % in cane

Sucrose % in first mill juice

and

Solids % in absolute juice

Solids % in first mill juice

tend to increase.

From figures regularly supplied to this Station, I have calculated for mills fluming cane the two ratios discussed in this article. As an average I find that for Yellow Caledonia flumed cane

$$\frac{\text{Sucrose in cane}}{\text{Sucrose in first expressed juice}} = .82 - .83$$

and

$$\frac{\text{Total solids in first expressed juice}}{\text{Total solids in absolute juice}} = .99 - 1.00$$

Under the conditions of flumings, no very constant ratio could be expected; and if this reasoning is to be applied to flumed cane, I think it would be necessary to actually determine the ratio experimentally from time to time, either in a hand mill with small quantities of cane, or in the factory mill by running without water long enough to obtain the necessary samples.

\* 3.90° Brix corresponds to 1.0117 specific gravity which may without sensible error be taken as the specific gravity of the solution.



## PART II

### SOME EXPERIMENTAL STUDIES ON THE MILLING OF CANES.

With the object of obtaining some information in regard to the economics of the extraction of juice by milling, it was thought that light might be thrown on certain points by the carrying out of definite trials under factory conditions supplemented by experiments with a small hand mill. Certain trials made with this object are described below, the points chiefly considered being :

1. A comparison of nine- and twelve-roller mill work.
2. The determination of the extraction at each mill.
3. Comparative trials with hot and cold water.
4. Comparative trials with and without the return of dilute juice.
5. The effect of increasing extractions on the amount of available sugar extracted.

*Nine-Roller Mill.*—The results which are given below were made in a nine-roller mill and crusher of recent construction, the rollers being of size 34"x78". During the tests it was grinding at the rate of 35 to 37 short tons of cane per hour. The cane milled was Lahaina, and, judging from the uniformity of the samples obtained from the crusher rolls, cane of even quality was milled during the whole series of experiments. The following four methods of applying maceration water were carried out :

- a. Hot water before last mill with return of third mill juice before second mill.
- b. Hot water before last mill with no return of third mill juice.
- c. Cold water before last mill with return of third mill juice before second mill.
- d. Hot water before both second and third mills and no return of diluted juice.

In conducting these trials, the method used was to systematically sample and analyze the bagasse coming from each mill. In order to obtain samples from the second mill, the supply of water or of juice in front of this mill was shut off for a period long enough to take a sample. At the same time samples of the juices were taken half hourly. Each trial lasted about eight hours. Two trials were made of the two first mentioned methods, and one only in the last two. The fibre in cane has been taken from

the routine analyses of the week during which these analyses were made. The samples of bagasse were analyzed by the method of hot-aqueous digestion,\* and care was taken to finely divide the samples. The fibre in the bagasse as entered up must be regarded as only approximately accurate. It has been determined by accepting a purity of 85, 80 and 70 in the residual juices in the first, second and third mill bagasses; and because of this approximate nature of the determination, it is only expressed in whole numbers.

These analyses afford means of calculating the total extraction at each mill from the formula †

$$\text{Extraction} = 100 - \frac{\text{fibre in cane}}{\text{fibre in bagasse}} \times \frac{\text{sucrose in bagasse} \times 100}{\text{sucrose in cane}}$$

whence subtracting that obtained by the previous mill or mills, the extraction at any one mill is obtained. The results obtained are set out in tabular form in Table I, where is given the analyses of the cane, bagasse and juice from each mill and the extraction at each mill of the series.

To obtain the amount of sugar in the canes I made a trial of half an hour's duration with dry crushing; the crusher juice, mixed juice and bagasse were carefully sampled over this period and analyzed; these analyses combined with a knowledge of the fibre in cane give data to calculate the per cent. sugar in cane whence a ratio converting sugar in cane and sugar in crusher juice follows; this ratio I found for this particular mill and canes to be .840.

On examining these results it is noticed that the highest extraction is obtained when a system of compound saturation is followed. The lowest result is obtained when all the water is added before the last mill; and an intermediate result, when the water is divided before the second and third mills.

Although it was attempted to keep the dilution constant throughout the series, considerably more water was used in the tests with single and with divided addition of water. In comparing results, this point should be remembered, since it accentuates the differences observed between the results obtained from the different methods.

Between the use of hot water and cold water, little difference, if any, is to be found. The very small advantage in favor of hot water is perhaps accounted for by the slightly higher dilution.

\* I am aware that this method has been strongly objected to, and Zammaron's method is often recommended. In my opinion, however, the bulk of the evidence is in favor of the direct-aqueous digestion, giving accurate results.

† This method should be known as Icery's; it was first given by him in 1869 in his classic memoir "Recherches sur le jus de la canne."

TABLE I.

Results obtained with 9-Roller Mill.

		Hot water with return of dilute Juices.	Hot water at 3rd Mill only.	Cold water with return of dilute Juices.	Hot water at 2nd and 3rd Mills.
Case	Fibre %.....	11.4	11.4	11.4	11.4
	Sucrose %.....	16.40	16.47	16.31	16.51
Mill I Bagasse	Sucrose %.....	10.09	9.90	9.98	10.20
	Water %.....	52.20	53.20	53.11	53.07
	Fibre %.....	36.	36.	36.	36.
Mill II Bagasse	Sucrose %.....	6.90	7.94	7.09	7.40
	Water %.....	48.90	47.40	49.45	48.15
	Fibre %.....	41.	43.	40.	43.
Mill III Bagasse	Sucrose %.....	4.37	4.75	4.48	4.60
	Water %.....	49.23	47.96	48.63	48.87
	Fibre %.....	45.	45.	45.	45.

		Brix	Sucrose %	Brix	Sucrose %	Brix	Sucrose %	Brix	Sucrose %
Juices	Crusher.	20.9	19.52	21.1	19.61	20.8	19.42	21.1	19.64
	Mill I...	20.7	19.12	20.7	19.20	20.9	19.40	21.0	19.24
	" II...	10.6	8.78	18.1	15.66	8.4	6.99	8.95	7.83
	" III.	3.9	3.15	3.9	3.16	3.6	2.89	3.7	2.93
	Mixed...	15.6	14.30	14.9	13.69	15.9	14.34	15.0	13.78

Dilution.....		33.9	41.62	30.8	40.6
Extraction at	Crusher and Mill I.	80.50	81.02	80.63	79.95
	Mill II.....	7.83	6.81	5.42	6.97
	" III.....	4.92	4.89	7.08	6.89
	Total.....	93.25	92.72	93.13	92.94

*Twelve-Roller Mill.*—In a twelve-roller mill, of similar size and construction to the nine-roller mill, I made a series of trials with hot water and with cold water, the system of saturation being as follows: Water was applied before the fourth mill; the fourth mill juice was returned in front of the third mill; the third, in front of the second; and the second, in front of the first on to the canes coming from the crusher, the juice going to the boiling house being taken from the crusher and from the first mill. As with the nine-roller mill, the sugar in the canes was deter-

mined by use of a ratio connecting sucrose in cane and sucrose in expressed juice. In this case a ratio of .835 was experimentally found. The fibre used in the calculation is that found as a weekly average in the routine analyses. The results of the trials are set forth in Table II. The comparison of the effect of hot water and of cold water leads to the same result as was obtained with the nine-roller mill; namely, that either is equally efficient.

TABLE II.  
Results obtained with 12-Roller Mill.

			Hot water with return of dilute Juices.	Cold water with return of dilute Juices.	Hot water at 3rd and 4th Mills.	
Cane	{	Fibre %.....	10.4	10.4	10.4	
		Sucrose %.....	17.35	17.55	17.72	
Mill I Bagasse	{	Sucrose %.....	11.89	11.87	11.14	
		Water %.....	56.10	56.07	54.75	
		Fibre %.....	30.	30.	31.	
Mill II Bagasse	{	Sucrose %.....	9.40	9.03	8.23	
		Water %.....	49.66	50.71	46.75	
		Fibre %.....	38.	38.	43.	
Mill III Bagasse	{	Sucrose %.....	7.14	7.38	5.30	
		Water %.....	47.18	48.13	49.65	
		Fibre %.....	43.	43.	44.	
Mill IV Bagasse	{	Sucrose %.....	4.90	4.82	4.40	
		Water %.....	47.27	47.63	44.38	
		Fibre %.....	45.	45.	50.	

		Brix	Sucrose %	Brix	Sucrose %	Brix	Sucrose %
Juices	{	Crusher..	22.35	20.77	22.66	20.90	23.20
		Mill I....	19.56	16.44	19.83	16.87	17.80
		“ II....	18.30	15.08	18.94	15.66	13.20
		“ III....	14.70	11.75	14.35	11.38	10.45
		“ IV....	9.55	7.47	9.73	7.62	7.70
		Mixed....	20.00	17.47	20.32	17.88	18.35

Dilution.....		11.7	11.5	26.4
Extraction at	{	Crusher and Mill I.....	76.2	76.6
		Mill II.....	9.0	8.9
		“ III.....	4.9	4.3
		“ IV.....	3.4	3.8
		Total.....		93.5

I also made a series of trials with the use of hot water before both third and fourth mills, returning the fourth mill juice in front of the second mill, and the third mill juice in front of the first mill, and taking juice to the boiling house from the crusher, first mill, and second mill. The results of the trials are given alongside the others; but, unfortunately, they are not very suited for comparison, since, judging from the analyses of the bagasse during these trials, the mill as a crushing machine was performing better than during the others. A much larger quantity of water was also used in these trials, as it was not found practical to efficiently divide the very moderate quantity of water which was used in the other trials.

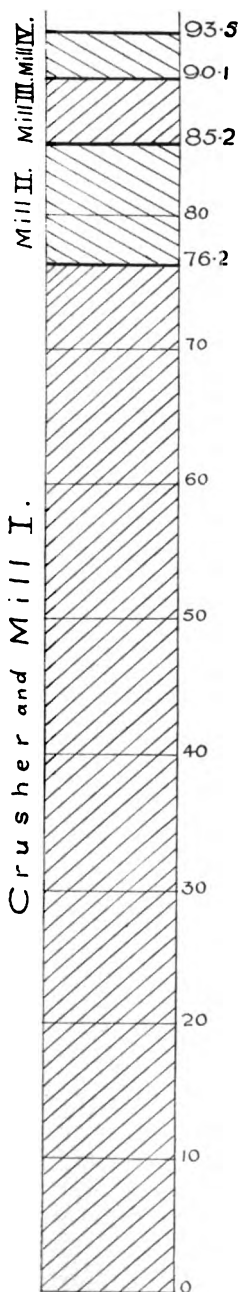
*Comparison of Nine- and Twelve-Roller Results.*—One of my objects in making these trials was to obtain some basis of comparison of nine- and twelve-roller mill work, and I selected these two mills for this purpose, as each is of the same size and grinds cane very similar in composition. The results of the trials, using the averages of hot and cold water compound maceration as a basis, are set out diagrammatically in *Fig. 1*, the chief points of difference are the much greater extraction at the first mill in the nine-roller set. This is of course due to the much larger quantity of cane treated in the twelve-roller set, 50 tons per hour as against 35. The return of the second mill juice in front of the first mill did not appear to have much effect, and this point is referred to later.

At the second mill the extraction at the nine-roller set is still in advance of the corresponding position in the twelve-roller mill set, although the difference is lessened. This is the result that would naturally follow from the less extracted material offered to the second mill in the case of the twelve-roller set. The extraction at the third mill is very nearly equal in both instances; and finally, the extraction at the last mill of the twelve-roller set allows the latter to pass that obtained at the nine-roller set.

Allowing for difference in fiber content, these trials lead to the conclusion that a twelve-roller set treats 50 tons of cane per hour as efficiently as a nine-roller set treats 35 tons with a dilution, however, of only 12% compared with one of 34%.

To my mind, the salient point of these trials is the great economy effected in operation of the twelve-roller set, due to a greater quantity of cane milled; and in the volume of juice to be treated, due to the less water necessary to obtain equally good results. In order to see the effect of decreasing the water in a nine-roller mill, I made similar trials, the results of which given in Table III below show in these trials that that quantity of water which in a twelve-roller mill gives an extraction considered satis-

*Extraction at XII Roller Mill 34" x 78".  
50 Tons of Cane per hour. 11.7% Dilution.*



*Extraction at IX Roller Mill 34" x 78".  
35 Tons of Cane per hour. 33.9% Dilution.*

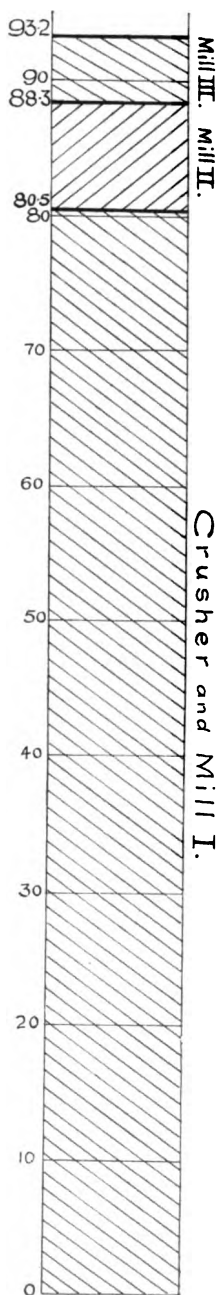


FIG. I.

factory, in a nine-roller mill gives very inferior results. Reference to the results already tabulated shows that this result is due to the combined effect of the last two units.

TABLE III.

Results obtained in a Nine-Roller Mill with moderate dilution and return of diluted juice:

Cane	{ Fibre %.....	11.4	
	{ Sucrose %.....	16.21	
Mill II	{ Sucrose %.....	8.70	
	{ Water %.....	51.7	
	{ Fibre %.....	37.	
Mill III	{ Sucrose %.....	6.10	
	{ Water %.....	46.3	
	{ Fibre %.....	45.0	
Juices		Brix.	Sucrose %
	{ Crusher .....	20.9	19.29
	{ Mill I.....	20.7	18.67
	{ " II.....	16.5	13.64
	{ " III.....	10.0	8.34
	{ Mixed .....	18.5	16.42
Dilution.....		11.0	
Extraction at	{ Crusher, Mill I and Mill II.....	83.5	
	{ Mill III.....	7.0	
	{ Total .....	90.5	

*The Effect of a High Extraction on the Sugar Available.*—A point which is frequently raised is, What is the effect of a high extraction on the purity of the mixed juice? i.e., on the amount of sugar capable of being obtained. Comparison of the results of a number of mills shows that there is no sudden drop in the purity as the extraction increases, and that the decrease of purity of the mixed juice with each increment of extraction is probably small and regular. Hence a determination of purity and extraction at two points in the neighborhood of an extraction of 90 should allow the decrease in purity as the extraction increases to be calculated for intermediate points. The two datum marks I selected were dry crushing and an extraction of about 93 to 94 as obtained in the ordinary routine. The average of a number of determinations gave the following results:

With crusher juice of 92.58 purity and an extraction of 93.5, the purity of the mixed juice was 87.64. With crusher juice of 92.87 purity and an extraction of 87, the purity of the mixed juice was 88.65.

In a second trial in a nine-roller mill, using water only at the third mill, I obtained somewhat different results which are expressed as under.

With crusher juice of 93.90 purity and an extraction of 88, the mixed juice was of purity 92.55 and of purity 90.51 with an extraction of 93.

Taking the average of these results an extraction of 93 may be considered as corresponding with a purity of 89.0, and one of 87 with a purity of 90.6; then by interpolating values the following table is readily constructed:

Extraction.	Purity.
87	90.6
88	90.4
89	90.1
90	89.8
91	89.6
92	89.3
93	89.0
94	88.8
95	88.5

These purities may, for a rough preliminary calculation, be taken as directly proportional to the sugar value of the juices so that increasing the extraction from 90 to 95 does not increase the

available sugar in this ratio, but rather in the ratio  $\frac{95}{90} \times \frac{88.5}{89.3}$

or 4.6%, instead of 5.5%, as calculated from the extraction alone.

Owing to the continually decreasing purity of the unexpressed juice, the extractions reported really imply that more available sugar has been extracted than the percentage on the total indicates. Thus for the nine-roller mill, at which I made trials, I estimate as under, using as a basis the average results obtained with hot and cold water with return of diluted juices.

The combined crusher and first mill juice was of purity 93 and contained 80.5% of the sugar in cane. The juice coming from the second mill contained 6.6% of the sugar in cane and was of purity 83. That coming from the last mill was of purity 80 and contained 6% of the sugar in the cane. The complete analyses of bagasse made for another purpose and discussed subsequently



would indicate a purity of about 70 for the residual juice. Taking refuse molasses at 45 true purity from the use of the  $\frac{s(j-m)}{j(s-m)}$  formula,<sup>7</sup> these juices are of value approximately proportional to 96, 85, 81, 66. Hence the relative values of the different juices are:

Crusher and first mill.....	96 x 80.5 = 74.8	} 85.2
Second mill.....	85 x 6.6 = 5.6	
Third mill.....	81 x 6.0 = 4.8	
Unexpressed juice.....	66 x 6.9 = 4.5	
	<hr/>	89.7

and the economic extraction, taking into account the decreasing purity of the unexpressed juice, is  $\frac{85.2 \times 100}{89.7} = 95.0$  where actually only 93.1% of the sugar has been extracted, and the proportional extraction at each mill is

First mill.....	83.4%
Second mill.....	6.3%
Third mill.....	5.3%
Unexpressed juice.....	5.0%

As these experiments gave only two points by which to judge the effect of increasing extraction on the amount of sugar available, I made a series of experiments crushing cane in a two manual hand mill. The mill was a three-roller mill with rollers 5"x4" and had the rollers adjusted by set screws passing through the head stocks. The mill was then essentially a rigid mill; and as the experiment showed, I was able to obtain a "crushing," judged by the fibre content of the bagasse, comparable in every way with that obtained by large mills on the factory scale. Indeed, the bagasse finally obtained was more disintegrated and pulverized than that obtained in most mills. In conducting the experiments detailed below, one kilo of cane split into strips was passed three times through the mill increasing the thickness of the feed at each operation. After the third crushing, when about 65% of juice had been obtained, about 100 grams of water was distributed over the bagasse which was then again crushed. This operation was done in all five times, the expressed diluted juice being collected separately at each crushing. The bagasse was finally weighed and analyzed. In this way eight fractions of juice were collected, the analyses of each fraction being as below:

TABLE IV.

Fraction.	Weight % Cane.	Total Solids %	Sucrose %	Purity.	Value of $s(j-m)$
					$\frac{j(s-m)}{s(j-m)} \times 100$
1	34.7	19.10	17.71	92.7	95.5
2	16.0	19.20	17.23	89.7	92.6
3	13.0	19.04	16.70	87.7	90.4
4	9.8	13.22	11.64	88.0	90.7
5	11.3	7.22	6.01	83.2	85.3
6	10.0	5.50	4.44	80.8	82.3
7	12.0	4.00	3.16	79.0	79.9
8	11.6	2.86	2.17	75.9	75.7
Bagasse...	28.0	2.05	1.33	65.0	57.3

Referring to the above table, which represents the mean result of a series of experiments, the decreasing purity of each successive fraction of juice is well shown, except at the fourth fraction where an increase over the third is noticed. This increase, obtained in all the experiments, is not due to accident or error. The third fraction was obtained under very heavy pressure, and probably contained much rind tissue juice. The fourth fraction was the first obtained by adding water to the bagasse, and probably consisted largely of pith tissue juice (which had remained unexpressed), to the exclusion of rind tissue juice as the rind had not yet been sufficiently broken up to take up its proportion of water.

As the purity decreases so also does the amount of available sugar contained in a quantity of juice. The percentage of available sugar in each fraction has been calculated from the formula

available sugar =  $\frac{s(j-m)}{j(s-m)}$ —where  $s$  is the purity of the sugar,

$j$  of the juice, and  $m$  of the molasses, giving to  $s$  the value .975,  $m$  the value .45, and taking for  $j$  the observed purities; hence the product of the extraction into the corresponding value of the

expression  $\frac{j(s-m)}{s(j-m)}$  gives the amount of available sugar obtained

at that operation. In the table I give the extraction at each operation, the value of  $\frac{s(j-m)}{j(s-m)}$  and the product of these two

quantities, or the amount of sugar available at each operation per 100 sugar in cane. Referring to this table, it appears that of the 43.2 parts of sugar per 100 sugar in cane obtained at the first operation, 41.3 are available; of the 4.7 parts obtained at the fifth operation, 4.0 are available; and of the 2.6 parts left in the bagasse, only 1.5 are available.

TABLE V.

Fraction.	Sucrose obtained per 100 Sucrose in Cane.	Purity.	Value of $\frac{s(j-m)}{j(s-m)} \times 100$	Product of Cols: 2 and 4 $\div$ 100
1	43.2	92.7	95.5	41.3
2	19.1	89.7	92.5	17.8
3	15.1	87.7	90.4	13.8
4	8.0	88.0	90.7	7.3
5	4.7	83.2	85.3	4.0
6	3.0	80.8	82.3	2.5
7	2.6	79.0	79.9	2.2
8	1.7	75.9	75.7	1.3
Bagasse....	2.6	69.0	57.3	1.5

Since the purity of each successive fraction of juice obtained decreases the earlier expressed portions have a higher available sugar value than the later ones, and 43.2 parts of sugar per 100 sugar in cane correspond to more than 43.2 parts of available sugar per 100 available sugar in cane. Accordingly, I have calculated the combined purities of the first and second fractions, of the first, second, and third fractions, etc., the corresponding values

of  $\frac{s(j-m)}{j(s-m)}$  the available sugar obtained at each extraction

and its percentage on the whole available sugar of the cane. For this last quantity, I propose the term "available extraction," i. e., when 93.1 parts of sugar per 100 sugar in cane have been extracted 94.4 parts of the available sugar in the cane have been obtained and this figure I think more nearly represents the factor controlling the economic work of the mill. These values are given in Table VI.

TABLE VI.

Extraction.	Purity.	Value of $\frac{s(j-m)}{j(s-m)} \times 100$	Available Ex- traction.
43.2	92.7	95.5	45.0
62.3	91.9	94.7	64.4
77.4	91.1	94.0	79.5
85.4	90.8	93.7	87.4
90.1	90.4	93.2	91.8
93.1	90.1	92.9	94.4
95.7	89.8	92.6	96.9
97.4	89.5	92.3	98.4
100.0	88.9	91.7	100.0

The results given already afford a means of answering a question often put, namely, if the extraction is increased from, say, 93.1, which represents average work with a nine-roller mill, what gain can be expected from an extraction of 95.7 which might be obtained with a twelve-roller mill? According to results tabulated above, the economic extraction at these points is 94.4 and 96.9, so that the percentage increase in sugar in bags will be 2.64% and not 2.79% as calculated from the extraction alone.

It will be observed that the canes forming the basis of this experiment were of high, but not of abnormal, purity. At the time of making these experiments, I did not have available, canes of low purity, and it may naturally be asked what will be the result on the economic extraction when such canes are being milled. If it be assumed that the purity of the absolute juice of the cane is proportional to the first expressed juice, then it would be possible to calculate out the purities of any fraction when the purity of the first expressed juice is known, using the experimental results already given as a basis. To test this supposition, I took a very larger number of actual factory results, and divided them into two portions—high purity and low purity, and then took the average of the purities of the first expressed and mixed juices. The results of the calculation are as below:

	High.	Low.
Purity of first expressed juice.....	94.40	87.60
Purity of mixed juice.....	87.48	85.13
Purity of first expressed juice		
.....	1.033	1.029
Purity of mixed juice		

This calculation, I think, shows that the purity of the absolute juice of the cane is proportional to that of the expressed juice; hence by simple calculations the purity and value of each successive fraction of expressed juice can be obtained when the purity of the initially expressed juice is known. Thus if the purity of the first expressed juice is 85, it is, I think, fair to estimate that

the purity of an eighth fraction will be  $\frac{85 \times 75.9}{92.7}$  using the values

found in Table V as a basis of calculation.\*

As purities representative of average and low purities in first expressed juice, I have taken 85 and 80; and on the lines imme-

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\* Of course the figures obtained will be affected by the amount of first expressed juice, by the mutual proportion of parenchyma and rind tissue, so that this calculation can at best be regard as only approximate.

ciately above, I have calculated the purity at each successive fraction, the corresponding value of  $\frac{s(j-m)}{j(s-m)}$ , the amount of available sugar obtained at each fraction, and the corresponding quantities for the total extraction at the end of each fraction, and the economic extraction at the same points.

The results of the calculation are given in Tables VII, VIII, IX and X, in form similar to those already described. Tables VII and VIII refer to a purity of 85 in first expressed juice, and Tables IX and X refer to a purity of 80 in first expressed juice.

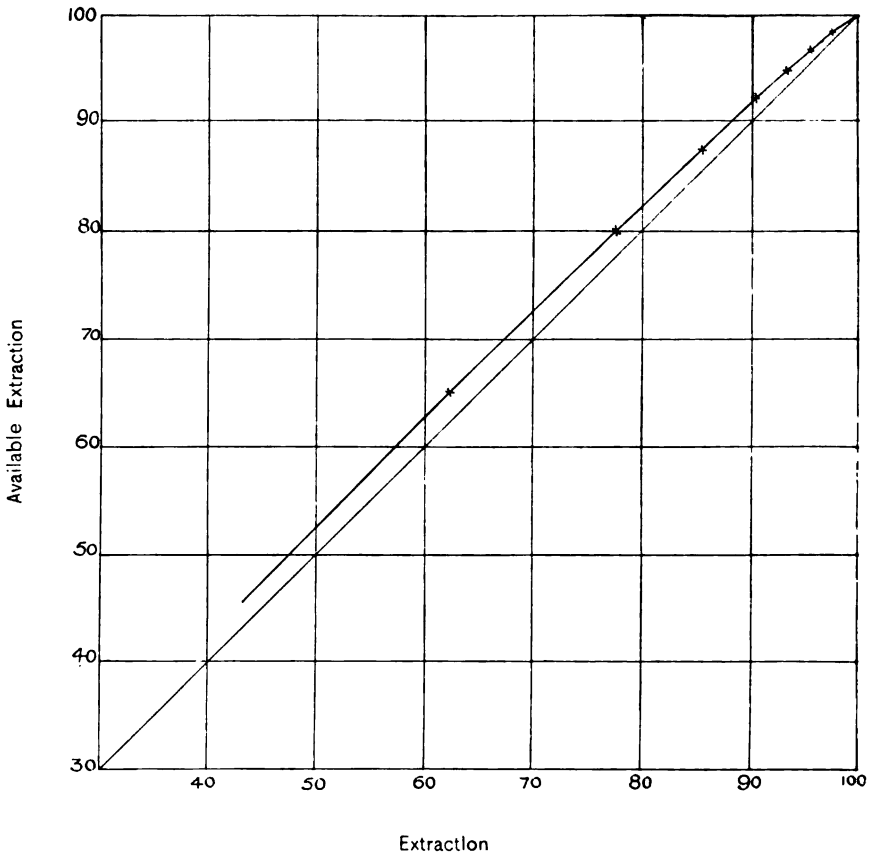


FIG. 2.

The figures so obtained are similar to those resulting with canes of high purity giving, however, a proportionally higher economic extraction at the earlier stages, due to the large influence of the very impure juice obtained in the later fractions.

The results obtained and already set out in tabular form lend themselves to graphical representation. In *Fig. 2* I give the available extraction curve obtained by plotting the extraction on the horizontal line and the corresponding available extraction vertically. The extraction curve is shown also, and is obtained by plotting the extraction both vertically and horizontally, and is, of course, a straight line inclined to the horizontal at  $45^\circ$ .

TABLE VII.

Fraction.	Sucrose obtained per 100 Sucrose in Cane.	Purity.	Value of $\frac{s(j-m)}{j(s-m)} \times 100$	Product of Cols: 2 and 4 $\div$ 100
1	43.2	85.0	87.4	37.9
2	19.1	82.2	84.0	16.1
3	15.1	80.4	81.7	12.3
4	8.0	80.7	82.0	6.6
5	4.7	76.3	76.2	3.6
6	3.0	74.1	72.9	2.5
7	2.6	72.4	70.3	1.9
8	1.7	69.6	65.6	1.2
Bagasse..	2.6	59.6	45.5	1.2

TABLE VIII.

Extraction.	Purity.	Value of $\frac{s(j-m)}{j(s-m)} \times 100$	Available Extraction.
43.2	85.0	87.4	45.7
62.3	84.1	86.3	65.1
77.4	83.4	85.5	79.9
85.4	83.1	85.1	87.8
90.1	82.8	84.8	92.2
93.1	82.5	84.4	94.9
95.7	82.2	84.0	97.5
97.4	82.0	83.8	98.7
100.0	81.4	83.0	100.0

TABLE IX.

Fraction.	Sucrose obtained per 100 Sucrose in Cane.	Purity.	Value of $\frac{s(j-m)}{j(s-m)} \times 100$	Product of Cols: 2 and 4 $\div$ 100
1	43.1	80.0	81.2	35.2
2	19.1	77.4	77.7	14.8
3	15.1	75.7	75.3	11.5
4	8.0	75.9	75.6	6.0
5	4.7	71.8	69.3	3.3
6	3.0	69.7	65.7	2.0
7	2.6	68.2	63.2	1.7
8	1.7	65.5	58.1	1.0
Bagasse..	2.6	56.1	36.7	1.0

TABLE X.

Extraction.	Purity.	Value of $\frac{s(j-m)}{j(s-m)} \times 100$	Available Extraction.
43.2	80.0	81.2	46.0
62.3	79.2	80.1	65.4
77.4	78.5	79.2	80.4
85.4	78.3	78.9	88.2
90.1	77.9	78.4	92.6
93.1	77.7	78.1	95.1
95.7	77.4	77.6	97.4
97.4	77.2	77.3	98.7
100.0	76.6	76.5	100.0

In *Fig. 3* I have plotted the purities of each successive fraction of juice and immediately above the corresponding values of the expression  $\frac{s(j-m)}{j(s-m)}$ ; this curve shows the fall in purity and in available sugar with each successive fraction of juice extraction.

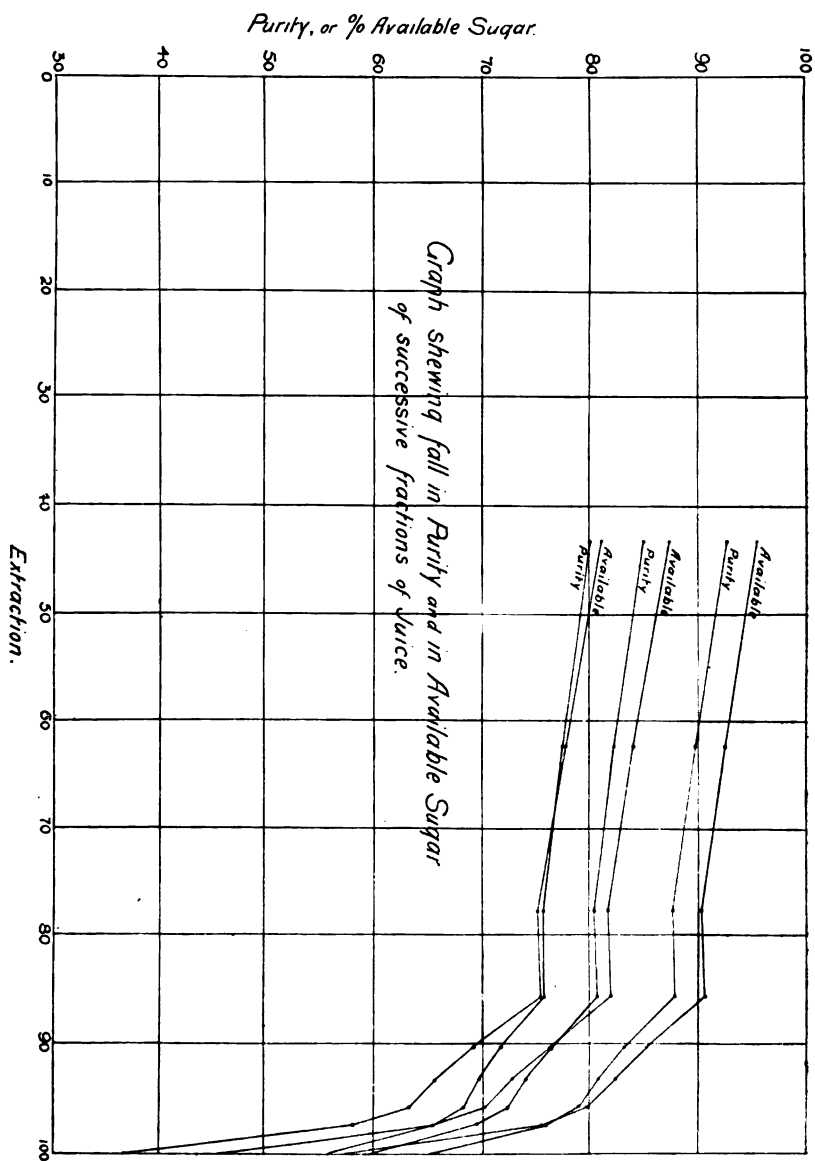


FIG. 3.



In *Fig. 4* I have plotted the total extraction at each point on the horizontal line with the purities and amount of available sugar in the whole quantity of juice extracted, on the vertical scale; the product of the height of the available curve at any point into the extraction at that point representing the available extraction at that point.

I have not made any mention at all of the financial aspect of high extraction, and have, I think, left this point out advisedly and have confined myself entirely to the problem in its experimental aspect. It would be quite easy to calculate by accepting certain conditions what would be the profit in raising the extraction from 93.1 to 95.7; but these points include so many variants, the capital account for a fourth mill, the sufficiency or insufficiency of the bagasse as fuel, the cost of coal, triple or quadruple evaporation, the price of sugar, marketing expenses, increased running expenses in labor and oil, etc., that I have thought it better to leave this question to those familiar with their own local conditions. Accepting the data I have brought forward here as a basis, the executive of any factory should have no difficulty in expressing these results in money units with reference to his own peculiar conditions.

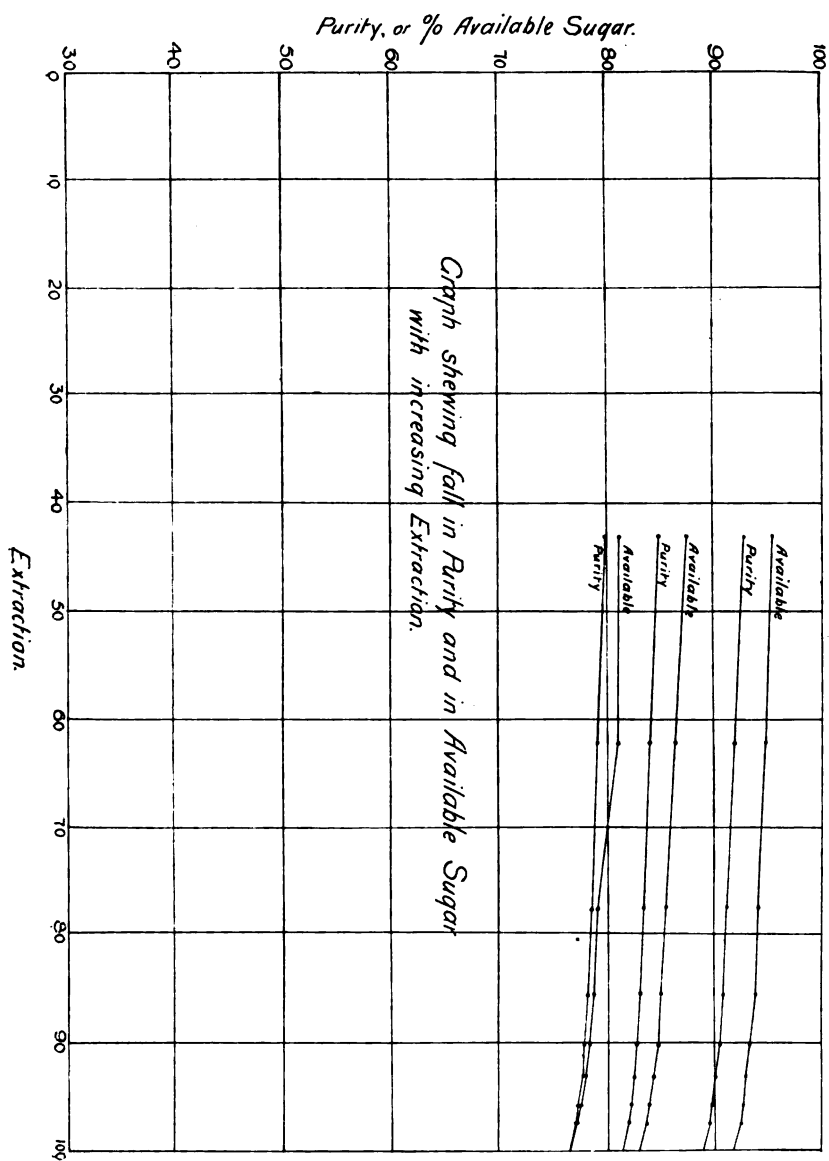


FIG. 4.

### PART III.

#### THE STRUCTURE OF THE CANE AS AFFECTING MILL WORK.

The observation, that increasing pressures produce a juice of inferior quality, dates back more than a generation, and, as is well known, is due to juice from the rind and nodes, being expressed only at higher pressures. Without going into details, it may be said that the cane contains three principle structures: first, a hard outer woody rind; second, a soft interior pith; and third, the fibro-vascular bundles. In another sense the cane may be divided into rind, nodes, and interior pith. This division is merely a convenient one for the purposes of this bulletin, and has no botanical significance.

Previous work on the structure of the cane has been done in Louisiana and in Java; in the latter district chiefly from the botano-physiological point of view. Thus Beeson<sup>8</sup> in Louisiana separated the cane into nodes and internodes, and obtained juice from both parts separately, finding a much inferior juice in the node than in the internode. Winter<sup>9</sup> in Java made determinations of the sugar and fibre in the center of the cane, the periphery, and in the rind, as well as determining the same quantities in the nodes and internodes. His results, as quoted by Geerligs,<sup>10</sup> are not quantitative, i.e., they do not give the proportion of rind, node, etc., nor is the purity of the juice in the various parts given. Browne<sup>11</sup> has also determined the fibre in the different parts of Louisiana cane, in the pith, in the fibro-vascular bundles, and in the rind.

In the analyses described below the division I adopted was into pith and rind and node. Thus the cane under analysis was first separated into node and internode by sawing through the node, the datum mark I adopted being the outer line of the zone of adventitious roots, and a corresponding distance on the other side. The portion thus obtained formed the material analyzed as the node. The rind was not separated from the node, so that this portion will consist mainly of rind, fibro-vascular bundles, and some pith. The other part consisting of the internode was stripped of the rind. On examining a clean cut cane, a fairly sharp line of demarcation between pith and rind can be found, and the rind was stripped off as nearly as possible through this line; this portion formed the rind, the remainder being analyzed

as pith. The separate portions were weighed and analyzed as regards moisture, fiber, solids, and sugar. The moisture was determined by drying in a vacuum oven at the temperature of water boiling under atmospheric pressure. The solids and sugar were determined by extracting the material with water in a Soxhlet apparatus. The extract was made up to definite volume in which the solids were determined by the refractometer, and the sugar by direct polarization. The fibre was obtained by difference.

The results of a series of experiments were as tabulated below :

		Rose Bamboo.	Y. Cale- donia.	Lahaina.	Lahaina.	Y. Cale- donia.
		Oahu.	Oahu.	Oahu.	Maui.	Kauai.
Whole Cane	Weight % Cane....	100.00	100.00	100.00	100.00	100.00
	Juice %.....	87.12	84.91	86.25	88.40	84.45
	Fibre %.....	12.88	15.09	13.75	11.60	15.55
	Solids %.....	14.70	15.83	16.03	20.10	17.92
	Sugar %.....	13.25	13.04	13.28	18.14	15.36
	Water %.....	72.12	69.08	70.22	68.30	66.53
Pith	Weight % Cane....	74.28	66.90	72.45	61.77	67.15
	Juice %.....	91.90	90.43	90.11	94.78	91.20
	Fibre %.....	8.10	9.87	9.89	5.22	8.80
	Solids %.....	15.93	17.34	17.45	22.21	19.62
	Sugar %.....	14.80	15.06	15.11	21.11	17.52
	Water %.....	75.97	73.09	72.66	72.57	71.60
Rind	Weight % Cane....	9.57	15.27	12.28	14.34	15.80
	Juice %.....	62.11	65.92	72.73	69.98	64.92
	Fibre %.....	37.89	34.71	27.27	30.02	35.08
	Solids %.....	9.38	11.52	11.54	15.40	13.87
	Sugar %.....	6.46	7.44	7.50	11.10	10.00
	Water %.....	52.73	53.77	51.19	57.58	51.05
Node	Weight % Cane....	16.15	17.83	15.27	23.89	17.05
	Juice %.....	79.98	80.40	78.78	82.80	75.97
	Fibre %.....	20.02	19.60	21.22	17.20	24.03
	Solids %.....	12.22	13.86	12.88	17.43	15.07
	Sugar %.....	10.14	10.27	9.22	14.62	11.83
	Water %.....	67.76	66.54	65.90	65.37	60.90

From these figures I then calculated the composition of the juice in each portion of the cane, obtaining the figures tabulated below :

		Rose Bamboo.	Y. Cale- donia.	Lahaina.	Lahaina.	Y. Cale- donia.
		Oahu.	Oahu.	Oahu.	Maui.	Kauai.
Absolute Juice	Weight % Cane....	87.12	84.91	86.25	88.40	84.45
	Solids %.....	16.87	18.52	18.59	22.72	21.22
	Sugar %.....	15.22	15.35	15.39	20.52	18.19
	Purity.....	90.22	82.94	82.79	90.32	85.71
Fith Juice	Weight % Cane....	68.26	60.49	65.49	58.62	61.24
	Solids %.....	17.33	19.17	19.37	23.43	21.49
	Sugar %.....	16.10	16.65	16.76	22.27	19.20
	Purity.....	92.90	86.85	86.53	95.05	89.29
Rind Juice	Weight % Cane....	6.04	10.06	8.91	10.00	10.26
	Solids %.....	15.08	17.41	15.87	22.00	21.37
	Sugar %.....	10.40	11.29	10.30	15.86	15.40
	Purity.....	69.10	64.85	64.91	72.09	72.10
Node Juice	Weight % Cane....	12.82	14.36	11.85	19.78	12.95
	Solids %.....	15.28	17.24	16.29	21.05	19.83
	Sugar %.....	12.68	12.77	11.70	17.66	15.57
	Purity.....	82.98	74.07	71.81	83.90	78.50

I then calculated the amount of sugar contained in each portion per 100 sucrose in cane: the results are given below:

	Rose Bamboo.	Y. Cale- donia.	Lahaina.	Lahaina.	Y. Cale- donia.
	Oahu.	Oahu.	Oahu.	Maui.	Kauai.
Pith.....	83.0	77.3	82.4	72.2	76.6
Rind.....	4.7	8.7	6.9	8.8	10.3
Node.....	12.3	14.0	10.6	19.0	13.1

Owing to the different purities, different amounts of sugar are available in the different portions. I then calculated the available sugar in each portion using the  $\frac{s(j-m)}{j(s-m)}$  formula, where  $s$  is the purity of the bagged sugar;  $j$ , that of the juice; and  $m$ , that of the molasses, giving to  $s$  and  $m$  the values 97.5 and 45.0; and expressed the proportions of sugar available per 100 available sugar in the cane.

The results of the calculation are shown in the annexed table, which gives the distribution of the available sugar per 100 available sugar in the cane.

	Rose Bamboo.	Y. Cale- donia.	Lahaina.	Lahaina.	Y. Cale- donia.
	Oahu.	Oahu.	Oahu.	Maui.	Kauai.
Pith.....	85.4	82.0	86.4	75.8	79.9
Rind.....	3.3	5.9	4.7	6.6	8.2
Node.....	11.3	12.1	8.8	17.6	11.9

On examining the results given in the first table, it appears that that part of the cane which I have taken as representative of the node is intermediate in composition between the parts representative of the parenchyma and rind tissue; and in a very rough sense, it may be considered as composed of those parts which go to make up the parenchyma and rind tissue. It is then, I think, permissible to regard the cane as consisting of a soft interior portion made up of a low proportion, of spongy, absorbent fiber, and a juice of high sugar content and purity; and of a hard outer portion containing a large proportion of a resistant non-absorbent fiber, and a juice of low sugar content and low purity. Dividing the part I have called "node" equally between the pith and the rind tissue, the average composition of the canes forming the basis of this experiment will be:

Whole Cane	{	Weight per 100 Cane..	100.00	Juice	{	Weight per 100 Cane..	86.3
		Fibre %.....	13.7			Solids %.....	19.8
		Solids %.....	17.1			Sugar %.....	17.1
		Sugar %.....	14.8			Purity .....	86.4
Soft Part	{	Weight per 100 Cane..	77.0	Juice	{	Weight per 100 Cane..	70.8
		Fibre %.....	8.0			Solids %.....	20.2
		Solids %.....	18.5			Sugar %.....	18.5
		Sugar %.....	16.7			Purity .....	90.3
Hard Part	{	Weight per 100 Cane..	23.0	Juice	{	Weight per 100 Cane..	15.5
		Fibre %.....	33.0			Solids %.....	18.3
		Solids %.....	12.3			Sugar %.....	12.7
		Sugar %.....	8.5			Purity .....	69.1

I thought it would be of interest to attempt to trace these two portions through the process of milling. The first experiment I made was in a hand mill, crushing the cane until about 65% of juice had been obtained. The bagasse was then separated into two portions, the soft inner part and the hard outer part. These two parts were weighed and analyzed separately, following the methods described on page 8. This method is of course extremely rough, as nothing but a separation into two parts, one consisting mostly of pith and one consisting mostly of rind, could

be obtained. Further, as the juice flows from the cane, some of the first expressed juice from the interior portion will flow on to and be retained by the rind. The results of a series of experiments are given below:

		Lahaina.	Rose Bamboo.	Y. Cale- donia.	Y. Cale- donia.
		Maui.	Oahu.	Kauai.	Oahu.
Expressed Juice	Weight per 100 Cane.....	70.99	66.75	65.60	64.64
	Solids %.....	24.22	17.70	21.68	18.73
	Sugar %.....	21.94	16.42	18.42	16.85
	Purity .....	90.58	92.77	84.97	89.96
Pith Bagasse	Weight per 100 Cane.....	13.35	15.74	14.40	14.69
	Solids %.....	15.29	11.57	12.20	12.20
	Sugar %.....	13.46	10.32	9.00	10.00
	Water %.....	52.32	56.16	49.21	54.52
	Fibre %.....	31.39	31.27	38.59	33.28
Rind Bagasse	Weight per 100 Cane.....	15.66	17.51	20.00	20.67
	Solids %.....	13.26	9.40	11.09	9.92
	Sugar %.....	10.37	7.22	7.45	5.68
	Water %.....	53.90	54.00	46.68	49.97
	Fibre %.....	32.84	36.60	42.23	40.11

Previously I had found an average of 8% fiber in the soft portion of the cane. The pith bagasse in these experiments contained on an average 34% of fiber. The weight of bagasse obtained

from the pith per 100 of pith is then  $\frac{8 \times 100}{34} = 24\%$  and of juice  $\frac{76}{92} = 83\%$ . The hard por-

tion of the cane contained originally 33% of fiber, and after crushing contained 38%, that is to say, that very little rind juice had been expressed. Assuming, as I think it is justifiable to do, that in larger mills obtaining 65% of juice on cane a similar state obtains, then it may be said that the first crushing obtains an extraction of about 80% of the pith juice and an extraction of nothing to a small quantity of rind tissue juice, and any rind tissue juice that is expressed is obtained in the later mills.

To further follow up this question, I obtained samples of bagasse from the first, second, third, fourth and fifth mills of a train of mills and separated this bagasse by picking out by hand into two portions one representative of the soft interior portion of the cane and one representative of the hard outer portion.

In the first and second mills this could be easily done, but in the later mills the separation was more imperfect, although the soft interior part could still be readily distinguished from the hard outer portion. In some of these experiments bagasse direct from the mill was used, and in these the moisture in the two portions was determined separately. In others, bagasse dried at the temperature of boiling water and kept in air-tight "Mason" jars, was used. In these cases the water was determined in the bagasse as a whole, but, it was found that there was very little difference in the water content of the two portions.

The results of the analyses are given below :

BAGASSE FROM A TWELVE-ROLLER TRAIN.

		Mill I.	Mill II.	Mill. III.	Mill V.
Pith Bagasse	Weight per 100 Bagasse	53.33	48.62	50.0	51.25
	Sugar %.....	11.33	7.19	3.78	2.87
	Fibre %.....	33.59	41.58	45.63	46.91
Rind Bagasse	Weight per 100 Bagasse	46.67	51.38	50.0	48.75
	Sugar %.....	9.12	7.13	4.34	4.06
	Fibre %.....	35.15	41.54	44.90	46.67
Whole Bagasse	Weight per 100 Bagasse	100.0	100.0	100.0	100.0
	Sugar %.....	10.34	7.16	4.06	3.51
	Fibre %.....	34.32	41.56	45.26	46.87

BAGASSE FROM A FIFTEEN-ROLLER TRAIN.

		Mill III.	Mill V
Pith Bagasse	Weight per 100 Bagasse.....	48.50	50.0
	Sugar %.....	3.86	2.70
	Fibre %.....	46.83	49.40
Rind Bagasse	Weight per 100 Bagasse.....	51.50	50.0
	Sugar %.....	4.66	3.57
	Fibre %.....	45.90	48.60
Whole Bagasse	Weight per 100 Bagasse.....	100.0	100.0
	Sugar %.....	4.30	3.13
	Fibre %.....	45.99	49.00

The point of great interest in these analyses, and to determine which these analyses were made, is that the pith bagasse originally contained more sugar than the rind bagasse; at the second mill the amount of sugar in either is the same; at the subsequent



mills the rind bagasse contains more sugar than does the pith, that is to say, the soft interior portion of the cane has yielded a much higher extraction than has the hard outer rind, and the extraction in its usual sense is of course the combined effect of these two quantities.

To obtain some idea of what these extractions are, I proceed as under:

The canes worked up at the twelve-roller mill whence the bagasse, the analyses of which are given in the above table, was derived, were of very high sugar content, and are represented by the analyses of the canes given in the fourth column of the Table on page 25, which came from the mill supplying the bagasse. The sample of cane I received, however, was much sweeter than those forming the week's material at the mill in question, and the canes would be more nearly represented by the following composition:

Soft Part	Weight %.....	75
	Fibre %.....	5
	Sugar %.....	20
Hard Part	Weight %.....	25
	Fibre %.....	30
	Sugar %.....	10
Whole Cane	Weight %.....	100
	Fibre %.....	11.25
	Sugar %.....	17.50

Thus using the analyses detailed above the extraction as regards the pith and rind separately appear:

	Mill I	Mill II.	Mill III	Mill IV.
Extraction per 100 Sugar in pith	91.6	95.7	97.9	98.5
“ “ “ “ “ cane	78.5	82.0	83.9	84.5
“ “ “ “ “ rind	22.2	48.3	71.0	73.9
“ “ “ “ “ cane	3.2	6.9	10.1	10.5
Total	81.7	88.9	94.0	95.0

These results show that the milling process is very effective so far as regards the soft inferior pith, but very crude as regards the extraction of sugar from the hard outer rind; probably with saturation processes using imbibition very little of the water is taken up by the rind tissue; an increased extraction is then to be looked for by any of the following methods:

1. Higher pressures resulting in the greater rupture of the rind tissue, giving at once a higher expression and a material more suited for the absorption of water.

2. More effective disintegration of the rind tissue to be obtained by the use of knives, shredders, crushers, or heavily indented rollers, several patterns of which have recently been placed on the market.

3. More rational means of applying the added water such as by the use of a series of injectors, as recently suggested by L. Pellet,<sup>12</sup> in place of a perforated pipe, or by the use of macerating baths through which the bagasse is drawn.

Higher pressures have been advocated in preference to the exaggerated use of water quite recently by A. Musy<sup>13</sup> who quotes exceptionally good results as obtained by a Hamilton (Triangular Headstock) mill built by the Krajewski-Pesant Co. and at work in Cuba; he is inclined to relegate the maceration process to the second place and writes as follows:

"Thus the maceration, instead of being the principal item in the milling process will be relegated to its proper place—the second one—and it will be finally admitted that the true economy in the grinding of the sugar cane must be obtained by the use of a moderate number of mills—three as a maximum—and of a limited quantity of maceration water."

So far as increasing mill pressures indicate a greater rupture of the hard outer rind of the cane, my results are in accordance with those quoted. However, as far as these islands are concerned with the existing mill pressures, the data at hand point to the economic superiority of the twelve- and fifteen-roller sets.

There remains one point more to be mentioned on which these analyses throw light. It not infrequently happens that while the fibre remains of constant percentage, the extraction varies largely, milling conditions remaining the same. Such a variation can be readily understood on the assumption that while the total amount of fibre remains the same, its distribution between the pith and rind varies, an increase in the proportion of the latter being accompanied by a decrease in the extraction.

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- 
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  - <sup>2</sup> Abstract in Journal of the Society of Chemical Industry, XXVIII, 375.
  - <sup>3</sup> Bulletin de l'Association des Chimistes de Sucrerie, etc., XXII, 921.
  - <sup>4</sup> Bulletin de l'Association des Chimistes de Sucrerie, etc., XXII, 23.
  - <sup>5</sup> Calculations used in Cane Sugar Factories, p. 13.
  - <sup>6</sup> West Indian Bulletin, IX, 85.
  - <sup>7</sup> International Sugar Journal, No. 89.
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  - <sup>10</sup> Cane Sugar and Its Manufacture, p. 84.
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  - <sup>12</sup> Bulletin de l'Association des Chimistes de Sucrerie, etc., XXVII, 205.
  - <sup>13</sup> American Sugar Industry, XI, 469.









AGRICULTURAL AND CHEMICAL SERIES.

BULLETIN No. 31



REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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The Determination of Sucrose  
in Cane Molasses.

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BY NOËL DEERR

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HONOLULU, HAWAII.  
JULY, 1910.



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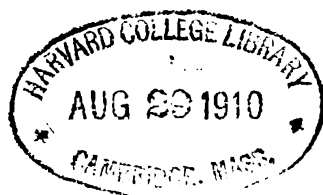
The Determination of Sucrose  
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*The Association*

## LETTER OF TRANSMITTAL.

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To the Experiment Station Committee of the  
Hawaiian Sugar Planters' Association,  
Honolulu, Hawaii.

Dear Sirs:—I herewith submit for publication, as Bulletin No. 31 of the Agricultural and Chemical Series of this Experiment Station, an article by Mr. Noël Deerr, Sugar Technologist, entitled: "The Determination of Sucrose in Cane Molasses."

Yours very truly,

C. F. ECKART,

Director.

Honolulu, Hawaii, July 8, 1910.



# THE DETERMINATION OF SUCROSE IN CANE MOLASSES.

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BY NOËL DEERR.

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In the determination of sugar in cane molasses, and in similar bodies that contain a large proportion of levulose, numerous sources of error exist; according to what procedure is followed very different results may be obtained.

The chief points to be considered are:

1. *The Effect of the Clarifying Agent Employed.*—The agent most extensively used for the preparation of sugar materials for polariscopic analysis is a solution of basic acetate of lead. Gill<sup>1</sup> first showed that the action of this agent increased the dextrorotation of cane sugar products, and quite correctly attributed this increase to the specific action of lead salts on the specific rotation of levulose. Later Geerligs<sup>2</sup> showed that, in the presence of chlorides and other bodies, with which lead forms insoluble compounds, levulose is precipitated from solution, although lead levulosate itself is soluble. Owing to this action of lead salts on levulose it is impossible to define what is the *direct reading* of a molasses when taken in the presence of alkaline lead salts. This point has been insisted on in late years particularly by H. Pellet, who advocates the use of Zamaron's reagent<sup>3</sup> consisting of neutral acetate of lead in combination with chloride of lime. With this agent he finds a constant *direct reading* independent of variation in the amount of the clarifying agent employed.

Spencer<sup>4</sup> overcomes the difficulty by using basic acetate of lead to slight excess, followed by acetic acid to acidity. The filtrate is further decolorized by the use of a bone black filter, using the usual precautions to obviate error due to the absorption of sugar by the bone black. Elsewhere the use of basic lead acetate is generally employed. Thus the official United States method reads<sup>5</sup>: "Dissolve the normal weight of the substance in water, clarify with lead subacetate, dilute to 100 cc.; filter and polarize the filtrate at 20° C. in a 20 cm. tube. The reading obtained is the direct reading before inversion."

In other publications the use of basic lead acetate is recommended with the precautions to "*avoid an excess.*" These direc-

tions are evidently ambiguous, for it is impossible to define an excess. Fifty cubic centimeters of a normal solution of molasses when clarified with 5 cc. of a solution of basic acetate of lead of 54 Brix may give a readable filtrate; a soluble sulphate will precipitate from this filtrate; hence in a sense, an excess of lead has been used. Conversely, the use of 40 cc. of the same solution of lead acetate per 50 cc. of a normal solution of waste molasses may not completely precipitate all the bodies capable of precipitation by lead, i. e., the filtrate so obtained on addition of more lead again forms a precipitate; hence, in a sense, an excess of lead has not been used.

Since the object of an analysis of cane molasses is generally to determine the cane sugar only, the removal of a part of the levulose from the solution is of no moment; hence the problem of obtaining the direct reading resolves itself into that of clarification and of obtaining the clear filtrate in such a condition that the lead salts have no effect on the specific rotation of levulose. This result can be obtained under the procedure proposed by Tervooen<sup>6</sup> whose results of great value and detail have passed unnoticed in the English written technical press; his routine to obtain the direct readings is as follows:

"Dissolve 35.816 (26.048 x 1.2 x 5.2 x 11.10) grams molasses in 250 cc. water with the addition of 40 cc. basic lead acetate; receive 100 cc. of the filtrate in a 100-110 cc. flask; add 1 cc. of 30 per cent acetic acid and 2 cc. of alumina cream, make up to 110 cc., then filter and polarize: the reading multiplied by 2 is the direct reading."

It is to be particularly noticed that in this scheme a larger quantity of basic lead acetate is used, whereby some levulose will be removed in the precipitate. The specific rotation of what remains in solution will be originally affected by the basic lead salt, and this effect is removed by the action of the acetic acid, added after the removal of the lead precipitate.

*The Volume Occupied by the Precipitate.*—That the volume occupied by the lead precipitate exercises an influence on the direct reading is the view held by Watts and Tempny<sup>7</sup>, by Weichman<sup>8</sup>, by Horne<sup>9</sup>, and by myself<sup>10</sup>. Its influence is denied by other chemists, notably M. M. Pellet père et fils, and by Fribourg<sup>11</sup>. Whichever view is correct no objection can be raised to a routine in which any error due to this source is eliminated or reduced to undetectable dimensions. If the direct reading be taken in dilute normal solution in a 20 cm. tube, as proposed by Sawyer<sup>12</sup>, whilst any error due to the volume of the precipitate is diminished, a correspondingly large

error of observation is introduced due to the small reading so obtained. This latter inconvenience can be removed by the employment of polariscopes capable of accommodating a 60 cm. tube. The degree to which this source of error is reduced is shown by the following calculation.

In an experiment with waste molasses I found that the volume of the precipitate from 26 grams was .5 cc.; the volume from 1-6 of this quantity is then .08 cc.; so that the volume of the solution is  $100 - .08 = 99.92$  cc. The reading observed in a 60 c.m. tube was 15 Ventzke degrees and, corrected to a volume of 100 cc., the reading would be  $14.98^\circ$ ; the difference is undetectable. If, however, a half normal solution were used, the volume of the precipitate would have been .25 cc. and the volume of the solution 99.75 cc. The reading in this concentration taken in a 20 cm. tube would then be  $14.98 \div .9975 = 14.91$ ; a difference quite detectable by a sensitive instrument.

*The Clerget Process.*—The Clerget process of inversion entailed the addition of 10 cc. of concentrated hydrochloric acid to 100 cc. of the sugar solution, heating on the water bath to  $68^\circ$  C., taking 15 minutes to reach this temperature. This routine is, I take it, the one generally employed in France, as it is the only one given by Fribourg<sup>13</sup>. The routine more generally followed, however, is that due to Herzfeld<sup>14</sup>. In this scheme 50 cc. of the sugar solution are made up to 75 cc. with the addition of 5 cc. of hydrochloric acid of specific gravity 1.18. The heating is continued for five minutes at  $67^\circ$  C.— $70^\circ$  C., 2 1-2 minutes being taken to reach this temperature, and in no case is the total period of heating allowed to exceed 10 minutes. Following both on the routine adopted and on the amount of sugar present, a different constant is found. That originally obtained by Clerget<sup>15</sup> referring to a concentration 16.35 grams in 110 cc. in the presence of 10 cc. of concentrated hydrochloric acid was 144. The Herzfeld constant is usually given as 142.66 and this number is often quoted as being a constant independent of the concentration of the sugar solution; actually, however, the constant falls with dilution, a fact expressly stated by Herzfeld, whose table of values is given below; his results have been completely confirmed by Ling<sup>16</sup>.



Grams Sugar per 100 cc.	Clerget Constant	Grams Sugar per 100 cc.	Clerget Constant
1	141.85	11	142.52
2	141.91	12	142.59
3	141.98	13	142.66
4	142.05	14	142.73
5	142.12	15	142.79
6	142.18	16	142.86
7	142.25	17	142.93
8	142.32	18	143.00
9	142.39	19	143.07
10	142.46	20	143.15

When following rigorously the inversion scheme as proposed by Herzfeld, a considerable experimental error is introduced due to the small magnitude of the inverted reading.

To diminish this source of error it would perhaps be more convenient to adhere to the original Clerget method; constants different from those appropriate to the Herzfeld method of inversion will necessarily result. As there appears to be on record no data showing the effect of concentration of sugar on the value of the original constant, I have made determinations of this following Clerget's original process:—100 cc. of sugar solution + 10 cc. of hydrochloric acid of specific gravity 1.18, the whole heated on a water bath to 68° C., taking 15 minutes to reach this temperature. I made three series of determinations in three polariscopes: two were of the firm Schmidt & Haensch, and these employed as the polarizing apparatus Lippich's half prism; the third was of the firm of J. & J. Fric, and was provided with the Jellet-Cornu polarizer; the normal weight for all the instruments was 26.048 grams in 100 Mohr's c. c. The light used was in two cases a kerosene duplex burner, and in the third case an electric light. The observations were made at a temperature of 28° C. to 28.5° C. The values of the Clerget constant as given below are referred of course to the value at 0° C. The constant is given to one place of decimals only, and all three of the series give the same result thus far.

Direct Reading in 20 cc. Tube	Value of Constant	Direct Reading in 20 cc. Tube	Value of Constant
100	144.5	50	143.3
95	144.3	45	143.2
90	144.2	40	143.1
85	144.1	35	142.9
80	144.0	30	142.8
75	143.9	25	142.6
70	143.8	20	142.5
65	143.7	15	142.3
60	143.6	10	142.2
55	143.4	5	142.1

It is suggested that the error due to the small reading in Herzfeld's routine may also be diminished by the following modification. To 50 cc. of the solution as used for the direct reading 2.75 cc. of concentrated hydrochloric acid is added and the inversion carried out as in the Herzfeld routine. The contents of the flask are then completed to 55 cc., in which concentration they are polarized. The constant appropriate to the analysis is selected from the table of Herzfeld's constants above, which is applicable, since the concentration of the acid is the same as in the Herzfeld routine.

It not infrequently occurs that a half normal molasses solution, after clarification with basic acetate of lead and subsequent inversion, gives a filtrate darker than can be read with any approach to accuracy. The addition of a little zinc dust to the inverted solution will always so decolorize the solution that it can be read easily and accurately in this concentration. This addition to the usual scheme was first proposed by Lindet<sup>17</sup>. The addition of a crystal of sulphite of soda, as suggested by Geerligs<sup>18</sup> has also a decoloring effect, but with the molasses with which I had to deal the zinc dust gives a much better decoloration.

The principles then under which the determination of sucrose in a cane molasses should be made are:

1. The use of a quantity of basic lead acetate such that the maximum decoloration is obtained, and at the same time much of the levulose (the chief disturbing influence) is eliminated in the precipitate.

2. The elimination following Tervooren of the specific effect of the basic lead salts on the rotation of levulose by acidification of the solution (with acetic acid and alumina cream).

3. The use of dilute solutions (1-6 normal) for the obtaining of the polariscopic reading, so as to eliminate any appreciable error due to the volume of the lead precipitate.

4. The use of long tubes, 60 cm. if possible, so as to eliminate errors due to a small reading.

5. A very slight modification of the Herzfeld procedure of inversion in which 50 cc. of solution are inverted with 2.75 cc. of hydrochloric acid of specific gravity 1.18; or use of the original Clerget procedure, combined with the selection of the appropriate constants.

6. The use of zinc dust as a decolorant of the inverted solution.

7. The obtaining of the direct and inverted readings at the same temperatures and in the same concentration.

8. The selection of the appropriate Clerget constant for the conditions of the analysis.

Referred to half normal weight the quantities of material required, etc. to fulfil these conditions, would read:

Place 9.881 (26.048 x 1-2 x 1-3 x 1.1 x 2) grams molasses in a 200 cc. flask; add enough basic acetate of lead to obtain the maximum decoloration (generally about 25 cc. of specific gravity 1.26) make up to the mark and filter. Transfer 50 cc. of the filtrate to a 50-55 cc. flask; add 1 cc. of a saturated solution of aluminium sulphate\*; make up to 55 cc.; filter and polarize in the 60 cm. tube. The observed reading multiplied by 2 is the direct reading = D. Transfer a second portion of 50 cc. to a 50-55 cc. flask; add 2.75 cc. of hydrochloric acid of specific gravity 1.18; invert, following the Herzfeld routine, or add 5 cc. of acid and invert, following the original Clerget procedure; add a small quantity, about .1 gram of zinc dust; make up to the mark; filter and polarize in a 60 cm. tube. The observed reading multiplied by 2 is the inverted reading = I.

Calculate the percentage of cane sugar from the expression,

$$\text{Sugar \%} = \frac{D - I}{X - \frac{t}{2}} \quad \text{where } t \text{ is the temperature at which}$$

the analysis is performed, and X is the appropriate constant.

\* I find that aluminium sulphate is a very suitable reagent for restoring the normal rotation of the levulose; the change in volume due to the precipitate of lead sulphate is negligible; the filtrate is very bright and capable of accurate reading.

In proposing such a routine scheme for the analysis of a molasses it is important that the results obtained be independent of the personal equation of the analyst. The only variation in the proposed method lies in the amount of basic lead acetate used. Analyses of molasses were made under the proposed routine, with varying quantities of basic lead acetate. These analyses given in tabular form below show a remarkable constancy in the sum of the readings and at the same time demonstrate the uselessness of attempting to give any specific value to the "*direct polarization*."

Molasses A was a factory product obtained from juices of low glucose content and containing only 12 % reducing sugars; molasses B was a material compounded of a partly inverted molasses, mixed with some impure levulose syrup.

## A.

cc. Basic Lead Acetate.	Direct Reading = D in 60 cm. Tube.	Inverted Reading = I in 60 cm. Tube.	D — I.
5	13.36	— 5.90	19.26
10	13.64	— 5.60	19.24
15	13.85	— 5.48	19.33
20	14.00	— 5.32	19.32
25	14.12	— 5.14	19.28
30	14.30	— 4.96	19.26
35	14.54	— 4.68	19.22
40	14.69	— 4.56	19.25

## B.

cc. Basic Lead Acetate.	Direct Reading = D in 60 cm. Tube.	Inverted Reading = I in 60 cm. Tube.	D — I.
5	1.90	Unreadable	.....
10	2.32	— 9.09	11.41
15	2.54	— 8.88	11.42
25	3.21	— 8.30	11.51
30	3.89	— 7.59	11.48
35	4.36	— 7.15	11.51
40	4.78	— 6.80	11.58

## REFERENCES.

1. *Journal of the Chemical Society*, April 1871.
2. I cannot find the original article, but see *International Sugar Journal*, No. 117.
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6. *Java Archief*, 1904, 321.
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15. *Annales de Chimie et de Physique* (3) 20, 186.
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# HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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**REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION**

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**Bagasse Analysis—Determination of  
Sugar and Moisture.**

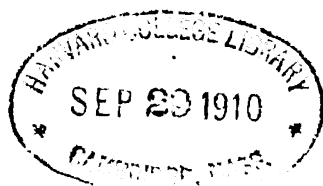
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**BY R. S. NORRIS**

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**HONOLULU, HAWAII  
1910**





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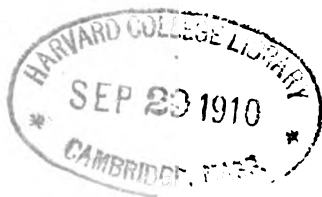
### ERRATUM.

Please note the following erratum in Bulletin 31, Agricultural and Chemical Series, Experiment Station, Hawaiian Sugar Planters' Association, which was recently forwarded to you:

Page 10, Line 21: For 9.881 read 9.551.

C. F. ECKART,  
Director.

Honolulu, Hawaii, August 2, 1910.



*The Sh*

## LETTER OF TRANSMITTAL.

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To the Experiment Station Committee of the  
Hawaiian Sugar Planters' Association.

Dear Sirs:—I herewith submit for publication as Bulletin No. 32 of the Agricultural and Chemical Series, an article by Dr. R. S. Norris, entitled: "Bagasse Analysis Determination of Sugar and Moisture.

Yours very truly,

C. F. ECKART,  
Director.

Honolulu, Hawaii, August 2, 1910.



# BAGASSE ANALYSIS---DETERMINATION OF SUGAR AND MOISTURE.

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BY R. S. NORRIS.

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## INTRODUCTION.

Rightly considered, the chemical control of a sugar factory bears the same relation to the actual processes of manufacture as the bookkeeping does to the business operations. And there is no other product of a cane sugar factory the analysis of which is so necessary to its proper control as that of the bagasse. The analysis of the juice is an important link in the system of control, but the results do not show directly, as does the analysis of the bagasse, how much of the sugar in the cane is being extracted and how much of it is going into the furnace. It is the recognition of this important position that bagasse analysis holds in a system of sugar factory control that has brought about the numerous investigations of this subject in several cane sugar countries during the last two years.\* And for this reason, also, it has been thought best to reinvestigate the subject in Hawaii. The present bulletin has to do with the determination of the sugar and the moisture in bagasse.

## SAMPLING.

The sampling of the bagasse is as essentially a part of the analysis as the determination of the different constituents. The value of the analyses in the control of the mill work is in fact more dependent on an accurate sampling than on the laboratory determinations, because the errors that are liable to occur in the

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\* "A knowledge of the composition of the bagasse as it leaves the mills is coming to be of very great importance, not only as affecting the mill work proper, but as bearing upon the whole factory work. All cane house analyses call for the work of a skilled chemist, but perhaps no other product calls for more judgment and resourcefulness upon his part than the bagasse analysis."—D. L. Davoll, Jr., *International Sugar Journal*, 1909, p. 387.

latter are small in comparison with those due to inaccurate sampling. Davoll expresses this none too strongly when he says in his paper on bagasse analysis: "\* \* \* \* the analysis is not at all difficult—it is the *sampling* that makes the demand upon his [the chemist's] skill, and it is the correct sampling that is all too frequently overlooked."

This being the case, it would seem important that more emphasis be placed on the sampling and more details be given of the correct method of taking samples than is usual in descriptive methods of control intended for the guidance of chemists in cane sugar factories.

### *Preservation of Bagasse Samples.*

No entirely satisfactory method has been found for preventing the loss of sugar in bagasse by fermentation. In a method of analysis described by Van Lookeren Campagne,<sup>1</sup> he sterilizes the bagasse by putting the sample in a sealed vessel and immersing it in the hot clarified juice for twenty minutes. He says nothing, however, of having determined to what extent the bagasse is actually sterilized by this process. Geerligs<sup>2</sup> investigated the effect of different chemical preservatives, and of heat, on the keeping qualities of bagasse. He found in one case that a formaldehyde solution prevented the fermentation of bagasse for twenty-four hours, while in another experiment of thirty hours' duration fermentation had begun. He found, furthermore, that bagasse could be made to withstand fermentation for as long as four days by heating it for an hour at 100° C. on three successive days. This method could not be applied, however, where it is desired to sub-sample the bagasse after it has been heated, on account of the evaporation of the moisture from portions of it. Another method, analogous to this, that has been suggested for preserving the bagasse samples so that fewer analyses will have to be made, is to combine the samples taken every hour for moisture determination after drying in a vacuum oven, and make one determination of the sugar from a sub-sample every twelve hours. In order to do this it would, of course, be necessary to know that none of the sucrose was decomposed during the drying. In a number of tests made to determine the effect on the sugar of drying the bagasse it was found that in some cases there was no decomposition, while in others there was a loss of sugar. In none of the tests is the length of time, as given, more than the minimum required for completely drying the sample.

	Before Drying.	After Drying.
Dried 6 hours at 100° C.....	{ 2.3 2.3	2.2 2.2
{ Dried 6 hours at 100° C.....	{ 2.6 2.7	2.5 2.5
{ Dried 1 hour at 110° C., 2 hours at 125° C.....	{	2.4 2.4
{ Dried 6 hours at 100° C.....	{ 3.5 3.5	3.2 3.2
{ Dried 4 hours at 100° C.....	{	3.4 3.4
Dried 3 hours at 100° C.....	{ 3.4 3.4	3.4 3.4
{ Dried 6 hours at 100° C.....	{ 4.0 4.0	3.8 3.6
{ Dried 3 hours at 100° C.....	{	3.7 3.7
Vacuum Oven 93° C., 4 hours.....	3.9	{ 3.6 3.6
Vacuum Oven 85° C., 4 hours.....	4.7	4.6
Vacuum Oven, 85° C., 3 hours.....	3.2	3.2
Vacuum Oven 100° C., 3 hours.....	{ 4.5 4.5	4.3
Vacuum Oven 100° C., 3 hours.....	{ 4.9 5.1	4.8

These results indicate that accurate determination of the sugar in the bagasse could not be made from the same sample used for determining moisture.

All of the bagasse used in these experiments was sprayed with formalin as soon as it was collected in order to prevent fermentation during the short time it was in transit from the mill to the Station laboratory. The bagasse had a strong odor of formaldehyde when it reached the laboratory. Two samples kept over for twenty-four hours after being weighed out showed a considerable loss in sugar.



	Polarization.
{ Fresh Bagasse.....	{ 3.7
	{ 3.7
{ After 24 hours.....	{ 3.2
	{ 3.2
{ Fresh Bagasse.....	{ 3.4
	{ 3.4
	{ 2.7
	{ 2.7
{ After 24 hours.....	{ 2.7
	{ 2.7

H. and L. Pellet<sup>3</sup> state that fresh cane chips can be kept for twelve hours without any loss of sugar by adding a little concentrated solution of ammonia to the vessel containing them. No figures are given in support of the statement, nor do they say whether it applies equally to bagasse samples.

For mill control work it would not be necessary generally to preserve the bagasse over twelve hours. However, in cases where it is very important to keep the samples for several hours after collection, it could probably best be done by treating them with formaldehyde gas from a generator. But, in general, the most satisfactory way is to analyze the samples as they are taken.

#### *Loss of Moisture During Preparation of Sample for Analysis.*

In none of the methods that have been described for bagasse analysis, except that of Davoll, is any attempt made to take account of the loss of moisture while the sample is being chopped up. Davoll's<sup>4</sup> device is to make two determinations of moisture—one in the original sample and one in the finely divided sample. If the same routine be followed every time a sample is prepared for analysis, the loss of moisture in chopping will be practically the same each time. This loss has been determined by the writer at a number of factories as follows: Between three hundred and four hundred grams of bagasse, just as collected from the last mill, were carefully weighed in a covered pasteboard box. It was then chopped up by the usual method—care being taken not to lose any of it during the chopping—and weighed again. When the hopper of the machine was kept covered during the chopping, the loss of moisture was usually about 2%; when not covered about 4%. The loss has never been found to vary appreciably during three or four days, and probably does not vary during longer periods. The loss in moisture can be conveniently allowed for in weighing out the sample. For instance, when the loss is 4%, a 48 or 96-gram weight may be made and used for weighing the bagasse samples.

A sample taken every hour for the determination of sugar and moisture should, under the most varied conditions, give a fair

average for these two constituents; but if the cane does not vary much and the mill runs smoothly, a sample once in three hours would probably answer the purpose quite as well. As the conditions vary considerably, especially in the smaller mills, the mill chemist must use his judgment as to when it is best to take the samples. In all cases the sample should be taken from the full length of the roller and the full depth of the bagasse blanket. This large sample is put into a box or pail, mixed quickly and thoroughly with the hands, and about 500 grams carried in a covered receptacle to the laboratory.

## DETERMINATION OF SUGAR.

### PREVIOUS WORK.

Mr. G. W. J. M. Zuur<sup>5</sup> described a method in 1893 in great detail, beginning with the sampling at the mill. In this method a sub-sample of 10 grams from that collected at frequent intervals at the mill is deposited every half hour in a flask containing four liters of cold water with a small amount of lead subacetate in it. At the end of twelve hours the solution with the 240 grams of bagasse is shaken up for five minutes and weighed. One hundred cubic centimeters of the solution are filtered off and weighed, and then polarized directly. The per cent. sugar is calculated from the weights and the polarization. Except for the fact that no account is taken of the loss of moisture during the elaborate method of sampling, it insures an average sample of the bagasse for analysis, but there can be no doubt, in the light of experience gained since that time, that digestion in cold water would not extract all of the sugar, and the results by this method would therefore be low.

Mr. C. J. Van Lookeren Campaigne<sup>1</sup> described a method in 1894, in which, also, the sampling was given considerable prominence. A sample of the bagasse from the mill is taken every ten minutes and put into a stoppered vessel. When several samples have been collected, the combined sample is placed in a closed iron cylinder and submerged in a hot liquid—clarified juice, for instance—for twenty minutes, and then cooled quickly, to preserve it. The sample for analysis is chopped up quickly with knives fine enough to pass through a sieve with ten millimeter meshes, and half a normal weight placed in a small glass cylinder and extracted in a Soxhlet extractor for three hours with 90% alcohol. The extract is evaporated to a small volume, made up to 50 cc. and polarized in a 200 mm. tube to get the percent. sugar. It is no doubt important to sterilize the bagasse if it is not analyzed very soon after being sampled; but there is an objection to heating it in this way before the sample for analysis is weighed out, as was pointed out above.

Zamaron<sup>6</sup> devised an apparatus for determining the sugar in cane, and later applied it to the analysis of bagasse. In his method 50 grams of bagasse are boiled with 150 cc. to 200 cc. of water for ten minutes; the solution drained off, and the operation repeated seven or eight times with fresh portions of hot water. After mixing and cooling the whole volume is made up to 1000 cc. or 1500 cc. This solution is polarized in a 400 mm. tube, and the polarization multiplied by 2.6048 gives the per cent. sugar. Few details are given on the important point of preparing the sample for analysis. The method has the fault, also, of requiring considerable attention, and is liable to some error on account of having to multiply the polariscope reading by such a large factor to get the per cent. sugar, since it is easily possible to make a mistake of a tenth in reading the polariscope.

The method described by Horne<sup>19</sup> in 1906 is exactly the same as adopted by the Hawaiian Sugar Chemists' Association in 1903 and in general use since then on these Islands.

Mr. D. L. Davoll, Jr.,<sup>4</sup> described, in a paper read at the International Congress of Applied Chemistry, London, June, 1909, a method which he has been using in Cuba. In this method a normal weight of bagasse is extracted for 1½ hours with hot 80% alcohol in a specially devised extractor of simple design, the extract being caught in a 100 cc. flask with expanded mouth, and polarized in a 400 mm. tube. Specific directions about the collection and preparation of the sample add much to the practical value of the method. The determination of sugar in bagasse by extraction with alcohol is by no means a new method. One very similar to that of Davoll was in use in Hawaii a number of years ago. The disadvantages of the method are the high price of alcohol, the danger of the alcoholic extract bumping and foaming up into the extractor, and the liability of error through concentration of the solution during filtration by evaporation of the alcohol. The extract also has a tendency to become dark colored and difficult to polarize. Because of these disadvantages the use of alcohol in beet sugar laboratories, which was once quite universal, has been almost entirely discontinued.

#### EXPERIMENTAL.

The first problem attacked in this investigation was to determine the effect of various conditions, such as length of time of digestion or extraction, amount of water, temperature, etc., on the results. It was necessary, in the first place, to ascertain how nearly equal results it was possible to get under the same conditions of working. Between four and five hundred grams of

bagasse\* were chopped up fine in a chopping machine, sifted through a wire sieve, four meshes to the inch, and thoroughly mixed; 50 grams were weighed out for each determination and about 500 cc. of water containing 5 cc. of a 5% solution of sodium carbonate added to it. The chopping machine used is the form commonly found in the sugar laboratories on these Islands, shown in Fig. 1, and manufactured by the Athol Manufacturing Co. of Athol, Mass., for a meat chopping machine. It gives excellent service if the knife is kept sharp and set down hard against the wooden bottom of the hopper. For convenience in mixing the solutions during digestion, flasks holding about 700 cc. were used, without condensers. After boiling the desired length of time the solutions were cooled a little, weighed and about 200 cc. strained off through cheesecloth into smaller

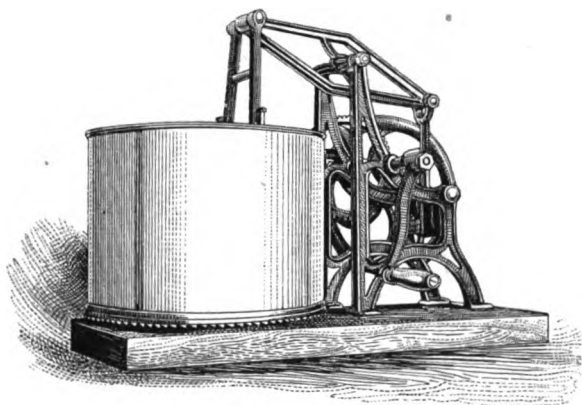


Fig 1

flasks and cooled to the laboratory temperature. From each solution 99 cc. were measured off in a 100 cc. flask and made up to the mark with lead subacetate solution of 54° Brix. The filtered solutions were polarized in 600 mm. tubes and the polarizations of the bagasse calculated in the usual way from the polariscope readings and the weights of the solutions. This was the routine followed in all determinations except when otherwise stated.

It was found possible to get results, without difficulty, within one-tenth of each other under similar conditions. The results were as follows:

---

\* The bagasse for these experiments came from the mills of plantations near Honolulu.

Samples.		1.	2.	3.	4.	5.	6.
A	Digested 20 minutes.....	4.1	4.1	4.1	4.0	4.0	4.1
B	“ 20 “ .....	4.0	4.0	4.0	4.0	4.0	4.0
C	“ 20 “ .....	5.0	4.9	4.9	4.9	4.9	..

## EFFECT OF TIME OF DIGESTION.

The question of the proper length of time for digestion has been a subject for discussion during the last few years, especially between Pellet and Geerligs. The former claimed<sup>7</sup> that the Carp<sup>8</sup> method as adopted by Geerligs,<sup>9</sup> in which the bagasse is boiled with water ten minutes, gives results from ten to thirty per cent. too low. Geerligs, on the other hand, claimed<sup>10</sup> that the Zamaron method,<sup>6</sup> which is favored by Pellet, gives too high results, because by long boiling of the bagasse with water a dextro-rotatory gum is formed which raises the polarization. He was able to isolate some of this gum by precipitating it with alcohol from a water solution that had been boiled for a considerable length of time with bagasse previously extracted with alcohol. Its solution in water polarized to the right, but did not give a precipitate with Fehling's solution on being heated with acid and neutralized. J. S. De Haan,<sup>11</sup> however, prepared some of this substance and found that it was precipitated from its water solution with basic lead acetate, and that therefore it could not be the cause of the high polarizations obtained by long boiling of the bagasse. Pellet in a more recent discussion<sup>12</sup> offers further proof that the method of single digestion for a short time gives too low results. If, after digestion, the liquid be drained off the bagasse, and that remaining in the bagasse be pressed out, the latter solution will be found to have the higher polarization. He was, furthermore, unable to obtain any dextro-rotatory substance by repeated extractions with water of the residue left after the usual treatment by the Zamaron method. He concludes therefore:

“1. That for the accurate determination of the sucrose in bagasse it is necessary to use the Zamaron apparatus, with successive treatments with boiling water. 2. That the methods employing a single treatment give results more or less approaching accuracy, depending on the division of the bagasse and the length of time of digestion. 3. That under the conditions of the method used in extracting the bagasse no dextro-rotatory substance is formed sufficient to influence the results.”

As regards the first conclusion, it might be pointed out that the fact that digestion with water for *ten minutes* gives low results is rather an argument for increasing the time of digesting than for changing the method. And regarding the second conclusion, there is no reason to suppose that the fineness of division of the bagasse would have any less influence on the results by the

Zamaron method than on those by the water digestion method. Davoll found that coarse bagasse gave lower results in the alcohol extraction than in the water digestion method.

Practically the same results were obtained by the writer, regardless of the length of time the solutions were digested, with the bagasse at first experimented on.

1.		2.	
Time Digested.	Polarization.	Time Digested.	Polarization.
5 min.	$\begin{cases} 3.6 \\ 3.6 \end{cases}$	15 min.	$\begin{cases} 3.4 \\ 3.4 \end{cases}$
10 min.	$\begin{cases} 3.6 \\ 3.6 \end{cases}$	30 min.	$\begin{cases} 3.4 \\ 3.4 \end{cases}$
15 min.	$\begin{cases} 3.5 \\ 3.6 \end{cases}$	45 min.	$\begin{cases} 3.5 \\ 3.5 \end{cases}$
3.		4.	
Time Digested.	Polarization.	Time Digested.	Polarization.
15 min.	$\begin{cases} 3.8 \\ 3.8 \end{cases}$	2 min.	$\begin{cases} 4.2 \\ 4.2 \end{cases}$
1 hr.	$\begin{cases} 3.8 \\ 3.8 \end{cases}$	15 min.	$\begin{cases} 4.2 \\ 4.2 \end{cases}$
1½ hrs.	$\begin{cases} 3.8 \\ 3.9 \end{cases}$		
5.		6.	
Time Digested.	Polarization.	Time Digested.	Polarization.
15 min.	$\begin{cases} 2.6 \\ 2.6 \\ 2.6 \\ 2.6 \end{cases}$	15 min.	$\begin{cases} 3.2 \\ 3.2 \end{cases}$
3 hrs.	$\begin{cases} 2.6 \\ 2.6 \\ 2.6 \\ 2.6 \end{cases}$	3 hrs.	$\begin{cases} 3.1 \\ 3.2 \end{cases}$
7.		8.	
Time Digested.	Polarization.	Time Digested.	Polarization.
10 min.	$\begin{cases} 2.4 \\ 2.3 \end{cases}$	15 min.	$\begin{cases} 3.0 \\ 3.0 \end{cases}$
1 hr.	$\begin{cases} 2.4 \\ 2.4 \end{cases}$	3 hrs.	$\begin{cases} 3.0 \\ 3.0 \end{cases}$

9.		10.	
Time Digested.	Polarization.	Time Digested.	Polarization.
15 min.	$\begin{cases} 2.6 \\ 2.6 \end{cases}$	15 min.	3.7
3 hrs.	$\begin{cases} 2.5 \\ 2.6 \end{cases}$	3 hrs.	$\begin{cases} 3.7 \\ 3.6 \end{cases}$
11.		12.	
Time Digested.	Polarization.	Time Digested.	Polarization.
15 min.	$\begin{cases} 5.0 \\ 4.9 \end{cases}$	15 min.	$\begin{cases} 5.3 \\ 5.3 \end{cases}$
1 hr.	$\begin{cases} 5.0 \\ 5.0 \end{cases}$	1 hr.	$\begin{cases} 5.3 \\ 5.3 \end{cases}$
13.		14.	
Time Digested.	Polarization.	Time Digested.	Polarization.
15 min.	$\begin{cases} 4.6 \\ 4.5 \end{cases}$	15 min.	$\begin{cases} 4.5 \\ 4.6 \end{cases}$
1 hr.	$\begin{cases} 4.6 \\ 4.5 \end{cases}$	1 hr.	$\begin{cases} 4.5 \\ 4.6 \end{cases}$
		3 hrs.	4.5
15.		16.	
Time Digested.	Polarization.	Time Digested.	Polarization.
1 hr.	$\begin{cases} 4.0 \\ 4.1 \end{cases}$	15 min.	$\begin{cases} 3.5 \\ 3.5 \end{cases}$
4 hrs.	$\begin{cases} 4.0 \\ 4.1 \end{cases}$	1 hr.	$\begin{cases} 3.5 \\ 3.6 \end{cases}$
		3 hrs.	$\begin{cases} 3.5 \\ 3.6 \end{cases}$

Later, with bagasse from another mill, the results were slightly higher with longer periods of digestion:

1.		2.	
Time Digested.	Polarization.	Time Digested.	Polarization.
15 min.	$\begin{cases} 3.0 \\ 3.0 \end{cases}$	15 min.	$\begin{cases} 3.1 \\ 3.2 \end{cases}$
1 hr.	$\begin{cases} 3.1 \\ 3.1 \end{cases}$	1 hr.	3.1
3 hrs.	$\begin{cases} 3.2 \\ 3.3 \end{cases}$	3 hrs.	$\begin{cases} 3.3 \\ 3.3 \end{cases}$

3.		4.	
Time Digested.	Polarization.	Time Digested.	Polarization.
15 min.	$\begin{cases} 3.3 \\ 3.3 \end{cases}$	15 min.	$\begin{cases} 2.2 \\ 2.2 \end{cases}$
1 hr.	3.4	1 hr.	$\begin{cases} 2.5 \\ 2.5 \end{cases}$
3 hrs.	$\begin{cases} 3.6 \\ 3.6 \end{cases}$	2 hrs.	$\begin{cases} 2.5 \\ 2.4 \end{cases}$
5.		6.	
Time Digested.	Polarization.	Time Digested.	Polarization.
15 min.	$\begin{cases} 4.8 \\ 4.9 \end{cases}$	15 min.	$\begin{cases} 3.3 \\ 3.4 \end{cases}$
1 hr.	$\begin{cases} 5.0 \\ 5.1 \end{cases}$	1 hr.	$\begin{cases} 3.4 \\ 3.5 \end{cases}$
7.		8.	
Time Digested.	Polarization.	Time Digested.	Polarization.
15 min.	$\begin{cases} 4.5 \\ 4.5 \end{cases}$	1 hr.	$\begin{cases} 4.5 \\ 4.6 \end{cases}$
2 hrs.	$\begin{cases} 4.8 \\ 4.9 \end{cases}$	5 hrs.	$\begin{cases} 4.6 \\ 4.7 \end{cases}$
9.			
Time Digested.	Polarization.		
15 min.	$\begin{cases} 2.8 \\ 2.7 \end{cases}$		
1 hr.	$\begin{cases} 2.8 \\ 2.9 \end{cases}$		
3 hrs.	$\begin{cases} 3.0 \\ 3.0 \end{cases}$		

The greatest difference in the polarizations of the bagasse in the experiments comparing the effect of different lengths of time of digestion, even when prolonged for as much as five hours, was only 0.3. An explanation of the higher polarizations with longer periods of digestion that suggests itself is that the solution surrounding the particles of bagasse which was used for the polarization became more concentrated by evaporation than that within the bagasse. As the tests were all made in duplicate, however, and frequently one of them was evaporated down a great deal more than the other without showing any difference in the calculated polarization of the bagasse, this would not be a valid explanation for the high results obtained by long digestion. The most probable explanation, it seems to the



writer, is that in some samples of bagasse there are a few very woody cells that have not been crushed by the mills, and the juice must be extracted from them by slow diffusion. In which case it would seem best to always digest the bagasse for about an hour.

Incidentally, in connection with the experiments on the effect of different lengths of time of digestion, it was found that with the first lot of bagasse which was extracted so quickly, the sugar could be practically all extracted with warm water and even cold water in an hour:

Treatment.	Polarization.
{ Boiled 15 min.....	{ 4.2
	{ 4.2
{ " 2 min.....	{ 4.2
	{ 4.2
{ Water at 75° C., 1 hr.....	{ 4.1
	{ 4.3
{ Boiled 2 hrs.....	{ 4.0
	{ 4.0
{ Water at 73° C., 1 hr.....	{ 3.9
	{ 3.9
{ Boiled 2 hrs.....	{ 3.4
	{ 3.5
{ Water 80° C., 1 hr.....	{ 3.4
	{ 3.4
{ Warm Water, shaken continuously for 3 hrs.....	{ 2.2
	{ 2.2
{ Boiled 1 hr.....	{ 2.4
	{ 2.4
{ Warm Water, shaken continuously for 3 hrs.....	{ 3.0
	{ 3.0
{ Boiled 15 min.....	{ 3.0
	{ 3.0
{ " 3 hrs.....	{ 3.0
	{ 3.0
{ Warm Water, shaken continuously for 3 hrs.....	{ 2.5
	{ 2.5
{ Boiled 15 min.....	{ 2.6
	{ 2.6
{ " 3 hrs.....	{ 2.5
	{ 2.6

Treatment.	Polarization.
{ Cold Water 1 hr.....	{ 1.6
	{ 1.7
{ Boiled 15 min.....	{ 1.7
	{ 1.8
{ Cold Water 1 hr.....	{ 2.0
	{ 2.2
{ Boiled 15 min.....	{ 2.3
	{ 2.3
{ " 1½ hrs.....	{ 2.3
	{ 2.3
{ Cold Water, shaken continuously for 3 hrs.....	3.0
{ Boiled 15 min.....	{ 3.2
	{ 3.2
{ " 3 hrs.....	{ 3.1
	{ 3.2
{ Cold Water, shaken continuously for 3 hrs.....	3.4
{ Boiled 15 min.....	3.7
{ " 3 hrs.....	{ 3.7
	{ 3.6

In order to determine whether any dextro-rotatory non-sugar was formed from bagasse from Hawaiian cane by boiling with water, two samples of 50 grams each of finely chopped bagasse were washed with cold water over night by means of a syphon extractor, a small amount of formalin being also added slowly to prevent fermentation. Enough cold water to cover the bagasse was then allowed to stand in contact with it for five hours after which it was drained off, a few drops of sodium carbonate solution added, and evaporated to about 35 cc. After adding lead subacetate, the solution was made up to 50 cc., filtered and polarized in a 600 mm. tube. The reading was zero. Each sample of bagasse was then boiled with 400 cc. of distilled water for 1½ hours. The solutions were evaporated as before, made up to 50 cc. and polarized in a 600 mm. tube. The readings were 0.25 and 0.2, equivalent to 0.035% sucrose in the bagasse.

A repetition of this experiment gave readings from the hot water extract of 0.0 and 0.1—the latter equivalent to 0.015% sucrose. Some of the bagasse which gave slightly higher readings with long extraction, was similarly treated, using 100 grams of bagasse and boiling the fiber for three hours. Polarizations in a 600 mm. tube from 50 cc. of solution gave readings of 0.2 and

0.3, equivalent to about 0.02% sucrose. It seems fair to conclude from these experiments: *That practically no dextrorotatory substance is formed from the fiber from Hawaiian cane, by boiling with water.* The small polariscope readings obtained were probably due to sucrose that was not extracted by the cold water.

#### EFFECT OF STATE OF DIVISION OF THE SAMPLE.

If there is a difference in the results obtained by digesting for ten or fifteen minutes or for an hour, with finely divided bagasse, as has been shown to be the case, it is to be expected that this difference would be exaggerated with coarsely cut samples. Pellet refers to this in an article previously mentioned.<sup>12</sup> A number of investigators on the subject of bagasse analysis have called attention to the importance of having the sample finely divided. Davoll<sup>4</sup> directs that the sample be chopped fine enough to pass through a sieve of nine meshes to the linear inch. He furthermore found that when the bagasse was coarsely cut the alcohol extraction method gave lower results than the method by digestion with water. Hazewinkel<sup>13</sup> made a detailed investigation of this point, by comparing the results obtained from bagasse chopped with a chopping knife and with a "Boot" chopping machine. His first results were irregular; but he found later that when the machine was set with an opening of 1 mm. the bagasse from it gave results from 0.4 to 0.8% higher (depending on the variety of cane) than that prepared with a chopping knife which left pieces 1 cm. in diameter.

The most noticeable point brought out in tests made by the writer to determine the difference in the results from fine and coarse bagasse, was the difficulty of getting duplicates with the latter. From which it would seem that there is a double reason for finely dividing the sample of bagasse for analysis, (1) to insure an average sample, (2) to make it possible to extract all the sugar during the time of digestion. The results were as follows:

Diameter of Largest Pieces 1 cm.	Polarization.
Digested 15 min.....	{ 2.0 2.3
Digested 1 hr.....	{ 2.4 2.4
Digested 3½ hours.....	{ 2.3 2.5

Diameter of Largest Pieces 2 cm.		Polarization.
Digested 15 min.		{ 2.8 3.0
Digested 1 hr.		{ 2.9 3.0
Digested 3½ hrs.		{ 2.9 3.1
Chopped fine } Digested 15 min }		{ 3.1 3.1
Diameter of Largest Pieces 2 cm.		Polarization.
Digested 15 min.		{ 3.9 4.0
Digested 1 hr.		{ 4.6 4.7
Chopped fine } Digested 15 min }		{ 4.5 4.5
Diameter of Largest Pieces 2 cm.		Polarization.
Digested 15 min.		{ 2.6 2.7
Digested 1 hr.		{ 2.8 2.9

#### EFFECT OF DIFFERENT REAGENTS ADDED TO THE DIGESTION WATER.

Besides the difference in length of time of digestion between the method of Carp and of the Hawaiian Sugar Chemists' Association, they also differ in the solution used for digestion. In the former, water alone is used, while in the latter a very weak solution of sodium carbonate is used. In still other methods a little lead subacetate solution is added to the digestion water. Several tests were made to determine whether these reagents made any difference in the results.

#### (1)

Time of Digestion.	Solution.	Polarization.
15 min.	Distilled Water.	{ 2.7 2.7
15 min.	2 cc. Sodium carbonate.	{ 2.6 2.7
15 min.	Lead subacetate.	{ 2.9 2.9
1 hr.	2 cc. Sodium carbonate.	{ 2.8 2.9

## (2)

1 hr.	2 cc. Sodium carbonate.....	{ 3.5
		{ 3.5
1 hr.	Lead subacetate.....	{ 3.4
		{ 3.4
15 min.	Lead subacetate.....	{ 3.5
		{ 3.5

## (3)

1 hr.	Distilled water.....	{ 3.9
		{ 3.9
1 hr.	2 cc. Sodium carbonate.....	{ 4.0
		{ 4.0

## (4)

15 min.	Distilled water.....	3.1
15 min.	2 cc. Sodium carbonate.....	{ 3.2
		{ 3.2

## (5)

1 hr.	2 cc. Sodium carbonate.....	{ 2.4
		{ 2.4
1 hr.	Lead subacetate.....	{ 2.3
		{ 2.3
10 min.	2 cc. Sodium carbonate.....	{ 2.4
		{ 2.3
10 min.	Lead subacetate.....	{ 2.3
		{ 2.3

## (6)

3 hrs.	Lead subacetate.....	{ 2.8
		{ 2.8
3 hrs.	2 cc. Sodium carbonate.....	{ 3.0
		{ 3.0
15 min.	2 cc. Sodium carbonate.....	{ 3.0
		{ 3.0

## (7)

3 hrs.	2 cc. Sodium carbonate.....	{ 2.5
		{ 2.6
3 hrs.	Lead subacetate.....	{ 2.3
		{ 2.4
15 min.	2 cc. Sodium carbonate.....	{ 2.6
		{ 2.6

## (8)

3 hrs.	Distilled water.....	{ 3.4
		{ 3.3
3 hrs.	2 cc. Sodium carbonate.....	{ 3.6
		{ 3.7
15 min.	2 cc. Sodium carbonate.....	3.7

With short periods of digestion the results of the tests were not altogether concordant, but with periods of an hour or more both water alone and with lead subacetate gave too low results. And, aside from any influence on the polarization, the sodium carbonate was found more satisfactory in that there was no difficulty in getting a clear filtrate when using it and taking 99 cc. of the solution with 1 cc. of lead subacetate solution of 54° Brix for the polarization. In the Hawaiian Sugar Chemists' Association method the directions specify the use of 5 cc. of a 5% solution of sodium carbonate to 50 grams of bagasse in 450 grams

of water. Repeated tests with different quantities of soda solution showed that 2 cc. were sufficient, and that the filtrate was clearer with this quantity than with either more or less. In those tests in which either water alone or mixed with a little lead subacetate solution were used, there was difficulty frequently in getting a clear filtrate for polarizing.

#### EFFECT OF AGITATION DURING DIGESTION.

It is a common practice in analyzing bagasse to allow the digestion to proceed without any shaking up or mixing of the bagasse with the solution. Working in this way the writer obtained quite irregular results.

Fine Sample.		Polarization.
1 hr., no shaking.....		{ 3.6
		{ 3.6
1 hr., shaken frequently .....		{ 3.4
		{ 3.4

Fine Sample.		Polarization.
1 hr., shaken frequently .....		{ 4.0
		{ 4.0
1 hr., no shaking, boiled slowly.....		{ 3.9
		{ 3.9
1 hr., no shaking, boiled violently.....		{ 4.2
		{ 4.0

Fine Sample.		Polarization.
1½ hrs., shaken frequently.....		{ 3.9
		{ 3.9
1 hr., no shaking.....		{ 3.9
		{ 4.1

Coarse Sample.		Polarization.
1 hr., shaken frequently .....		{ 4.6
		{ 4.7
1 hr., no shaking.....		{ 4.3
		{ 4.3

The results from the fine and the coarse samples were contradictory. The latter may have been due to the difficulty of getting an average sample; but, as good duplicates were obtained, the probability is that the extraction was uneven on account of the solution not being mixed, only that part of the sample where the solution was agitated by the boiling being thoroughly extracted. The result was the same with the fine sample when the boiling went on very slowly, but when the boiling was violent a higher result was obtained by not shaking—due probably to the concentration of the solution outside of the bagasse particles in certain portions of the mass.

## EFFECT OF ADDING WATER AFTER DIGESTION.

In the method of determining the sugar in bagasse by hot water digestion either no attempt is made to keep the solution at the same volume or it is kept constant by using a condenser or by adding water after the digestion is completed.

The use of a condenser is the most scientifically correct method, but it is troublesome, especially if the solution be shaken or otherwise mixed during the digestion, as it should be. The objection sometimes made to not replacing the water lost by evaporation is that the solution outside of the bagasse may become concentrated faster than it mixes with that within the bagasse. The writer believes that there is very little danger, practically, of an error from this source if the solution is properly mixed during digestion and is not boiled too violently. On the other hand the practice of making the solution up to a definite volume after digestion may lead to a considerable error, especially if the sample of bagasse is coarse and the solution is not thoroughly shaken up after the addition of the water. In the tests made on this point the samples were comparatively finely divided and the solutions were thoroughly shaken up after the addition of the water, but even under these conditions the results were low.

		Polarization.
{	Solution plus bagasse made up to 500 grams after digesting 1 hour.....	{ 3.4
	Boiled 1 hour, no water added.....	{ 3.7
{	Solution plus bagasse made up to 500 grams after digesting $\frac{1}{2}$ hour.....	{ 3.8
	Digested $\frac{3}{4}$ hour, warm water.....	{ 4.0
{	Solution plus bagasse made up to 500 grams after digesting 1 hour.....	{ 2.3
	Boiled 1 hour, no water added.....	{ 2.4

## COMPARISON BETWEEN WATER DIGESTION AND EXTRACTION WITH ALCOHOL AND WITH WATER.

		Polarization.
{	Water digestion.....	{ 2.6
	Normal weight extracted 4 hrs. with water, Soxhlet extractor, evaporated to 100 cc.....	{ 2.6
{	Water digestion.....	{ 3.2
	Extracted 4 hrs. water.....	{ 3.0
	Extracted 4 hrs. alcohol.....	{ 3.2
		{ 3.1

{ Water digestion .....	{ 2.4
{ Extracted 4 hrs. water.....	{ 2.4
{ Extracted 4 hrs. alcohol.....	{ 2.3
{ Extracted 4 hrs. alcohol.....	{ 2.3
{ Extracted 4 hrs. alcohol.....	{ 2.3
{ Water digestion .....	{ 3.0
{ Extracted with water 1 hour.....	{ 3.0
{ " " " 2 hours.....	{ 3.0
{ " " " 3 ".....	{ 3.0
{ " " " 4 ".....	{ 2.9
{ Water digestion.....	{ 2.6
{ Extracted with water 30 min.....	{ 2.6
{ " " " 40 ".....	{ 2.4
{ " " " 50 ".....	{ 2.4
{ " " " 1 hour.....	{ 2.5
{ Water digestion .....	{ 3.7
{ Extracted with water 50 min.....	{ 3.6
{ " " " 55 ".....	{ 3.4
{ " " " 1 hour.....	{ 3.4
{ Water digestion .....	{ 3.5
{ Extracted with water 1½ hours.....	{ 3.6
{ Extracted with water 1½ hours.....	{ 3.5
{ Extracted with water 1½ hours.....	{ 3.5
{ Water digestion .....	{ 3.3
{ Extracted with water 1½ hours.....	{ 3.3
{ Extracted with water 1½ hours.....	{ 3.2
{ Extracted with water 1½ hours.....	{ 3.2
{ Water digestion .....	{ 3.6
{ Extracted with water 2 hours.....	{ 3.6
{ Extracted with water 2 hours.....	{ 3.5
{ Extracted with water 2 hours.....	{ 3.5
{ Water digestion .....	{ 2.7
{ Extracted with water 1½ hours.....	{ 2.7
{ Extracted with water 1½ hours.....	{ 2.6
{ Extracted with water 1½ hours.....	{ 2.7
{ Water digestion .....	{ 3.0
{ Extracted with water 1½ hours.....	{ 3.0
{ " " " 2 hours.....	{ 3.1
{ " " " 2 hours.....	{ 3.1

The experiments show that practically the same results are obtained by water digestion and by extraction with alcohol or water for 1½ to 2 hours. The digestion method has the advantage of being the most convenient.



## A NEW METHOD.

The results of all the foregoing tests would indicate that the method of the Hawaiian Sugar Chemists' Association, with the addition of more explicit directions for preparing the sample, is better adapted for use in Hawaii than any other method that has been proposed, and gives as correct results as other methods. The weakest point in the method is the small reading on the polariscope, which, being easily liable to an error of one or two-tenths, may lead to a considerably larger error in the calculated polarization. This defect can be overcome by using very long polariscope tubes or a larger sample of the bagasse for digestion with a smaller proportionate amount of water. The first means is not expedient for practical work; the last can be made use of without difficulty, with the proper form of apparatus. The writer has devised and tested an apparatus in which 100 grams of bagasse can be digested with such an amount of water that the polariscope reading in a 200 mm. tube will be of about three-quarters of the magnitude of the polarization, or about one and a half times the polarization in a 400 mm. tube. With a bagasse of a polarization of four, for instance, the reading would be about three in a 200 mm. tube, and about six in a 400 mm. tube.

When a small amount of water is used, the solution with the

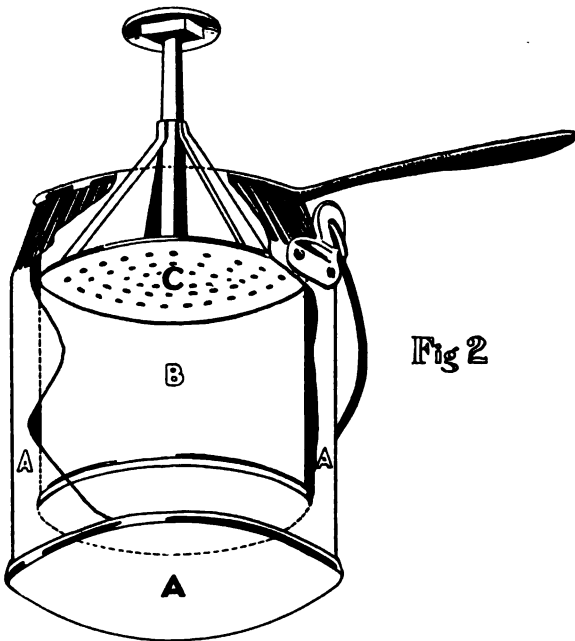


Fig 2

bagasse in it cannot be heated directly, therefore an apparatus somewhat similar to the "double-cooker" used for cooking cereals was adopted—see Fig. 2.

The apparatus consists of three parts,—(A) an outside cylindrical vessel for boiling water in, six inches (15 cm.) in height and five and a quarter inches (13 cm.) in diameter, crimped in at the top so that the inside vessel fits into it snugly; (B) an inside cylindrical vessel for digesting the sample in, four and a quarter inches (11 cm.) in height and four and a quarter inches (11 cm.) in diameter, with a straight handle and a rolled edge on top, upon which it rests in the outside vessel; (C) a tamp made of a disc of heavy metal with numerous holes in it and a rigid handle for pressing down on the bagasse. The latter should fit rather tightly into the inside vessel, so it may serve as a cover when not being used for pressing. With 100 grams of bagasse about 500 cc. of hot water containing 5 cc. of a 5% solution of sodium carbonate, should be used. This is digested for an hour—the solution being mixed every fifteen minutes by pressing down with the tamp, which is then made fast at the top of the vessel to serve as a cover and prevent evaporation.

In comparison with the Hawaiian Chemists' Association method, using 50 grams of bagasse, the following results were obtained:

Weight of Bagasse.	Polariscope Reading 600 mm. tube.	Polarization.
100 grams	16.1	4.9
50 "	{ 5.4	{ 4.9
	} 5.4	} 4.9
100 grams	10.2	4.8
50 "	{ 6.4	{ 4.8
	} 6.5	} 4.9
100 grams	9.3	3.6
50 "	{ 3.9	{ 3.6
	} 4.1	} 3.6
100 grams	7.6	3.6
50 "	{ 3.7	{ 3.6
	} 3.7	} 3.5
100 grams	9.2	4.6
50 "	{ 5.5	{ 4.6
	} 5.6	} 4.7
100 grams	10.4	4.4
50 "	{ 4.9	{ 4.5
	} 4.7	} 4.6
100 grams	9.9	4.0
50 "	{ 4.3	{ 4.1
	} 4.8	} 4.0

Weight of Bagasse.	Polariscope Reading 600 mm. tube.	Polarization.
100 grams	9.0	3.8
50 "	{ 4.2 4.0	{ 3.9 3.9
100 grams	9.2	3.8
50 "	4.8	3.9
100 grams	8.2	3.6
50 "	{ 3.8 4.0	{ 3.6 3.6
100 grams	{ 10.1 10.2	{ 4.1 3.9
50 "	{ 4.0 4.7	{ 3.8 4.1
100 grams	10.3	4.1
50 "	{ 4.4 4.2	{ 4.0 4.0
100 grams	10.3	4.5
50 "	{ 5.3 5.0	{ 4.5 4.4
100 grams	13.5	4.7
50 "	{ 5.1 5.1	{ 4.6 4.5
100 grams	11.5	4.6
50 "	5.0	4.6

Duplicate readings do not always correspond with the polarizations on account of the different weights of solution left after digestion.

By systematizing the procedure in the bagasse analysis with this apparatus it would no doubt be possible to obtain readings regularly of the same magnitude as the polarization in the 200 mm. tube, and readings of twice the polarization in the 400 mm. tube. Where it is necessary to use a 200 mm. tube, less water could be used for the digestion, as 50 cc. of the solution would be sufficient for polarizing.

It was found necessary in using the apparatus to add all the water to the bagasse at one time. When it was first tested the tamp was removed each time after using and the adhering solution was washed off into the digestion vessel. In this way extra water was added several times, and the results were low, as follows:

Weight of Sample.	Polarization.
100 grams	3.3
50 "	5.1
100 grams	3.3
50 "	4.0

100 grams	4.2
50 "	{ 4.5
	{ 4.6
100 grams	3.4
• 50 "	{ 4.1
	{ 4.2
100 grams	2.6
50 "	{ 3.4
	{ 3.5
100 grams	2.2
50 "	{ 4.4
	{ 4.3

The dimensions of the vessel in which the digestion is made also apparently affect the results. A larger apparatus in which 200 grams of bagasse could be digested was tried, but concordant results were not obtained. The only explanation that suggested itself was that the vessel was too deep and the column of solution too long for proper mixing during digestion. The correct dimensions of vessels for digesting larger samples could no doubt be found by experimenting, but since the use of larger samples would require larger scales than are to be found in most factory laboratories, it was not thought practically advisable, to undertake such experiments at this time.

Before using the apparatus in actual determinations it should be tested in comparison with the usual method in order to determine the right conditions for getting correct results.

## DETERMINATION OF MOISTURE.

### PREVIOUS WORK.

Verbeck<sup>14</sup> described a method for determining the moisture in bagasse in which duplicate samples are dried to constant weight in an air bath on large watch glasses. Very few details are given.

In a method devised by Nanninga<sup>15</sup> a sample of four or five grams of bagasse is dried for an hour in a thin glass tube placed in a water oven, with air dried with sulphuric acid passing over it. Numerous tests showed that the sample was completely dry in an hour, whereas it took seven hours to dry the same amount on watch glasses in the same oven. A very similar method to this has been quite recently described by Spencer,<sup>16</sup> wherein much larger samples—100 to 200 grams—are used and the air drawn through the bagasse is heated but not dried.

In the methods of the Hawaiian Sugar Chemists' Association, 1905, the determination of moisture is dismissed with the brief statement: "Moisture: found by drying to constant weight at 100° C."

Geerligs<sup>17</sup> in his Method of Analysis, directs that 20 grams be dried for 5 hours at 100° C. in a shallow dish. He considers it very important that the temperature shall not rise much above 100°. In tests made by the writer—to be discussed later—it was found that samples of finely divided bagasse could be heated for seven hours at 125° C. without any change taking place in it sufficient to affect its moisture free weight.

In a method described by Spencer<sup>18</sup> two kilograms (four and a half pounds) of bagasse are dried to constant weight in a bath heated by steam. He found that it takes about 24 hours to dry the sample. The method requires a special drying oven and special scales for this determination alone. In Davoll's<sup>4</sup> method 100 grams of bagasse are dried in a shallow tin box with a bottom of 80-mesh sieve to constant weight at 110° to 115° C., which require six hours.

#### EXPERIMENTAL.

The three factors that have the most influence on the moisture determination are the thickness of the layer of bagasse when drying, the temperature, and the length of time.

A common form of container used in factory laboratories for moisture samples, is a tin box about four inches (10 cm.) square and the same depth. They are used in this shape presumably on account of their convenience—certainly not because they are adapted to the accurate determination of moisture. Comparative tests with boxes of this form, each dimension 3½ inches (9 cm.) and shallow tin trays, 5½ by 8 inches (14 by 20 cm.) with sides ¾ in. (2 cm.) high and having an area of about 45 square inches (280 square cm.), using 50 grams bagasse, gave the following results:

		Percent Loss in Weight.				
		4 hrs.	5 hrs.	6 hrs.		
Square box	125° C.	44.0	45.0	46.0		
“ “	125° C.	46.0	46.0	46.0		
Shallow dish	125° C.	46.0	46.0	46.0		
		2 hrs.	3 hrs.	4 hrs.	5 hrs.	
Square box	125° C.	30.0	34.0	42.0	46.0	
“ “	125° C.	36.0	40.0	46.0	46.0	
Shallow dish	125° C.	46.0	46.0	46.0	46.0	
		2 hrs.	3 hrs.	4 hrs.	5 hrs.	6 hrs.
Square box	125° C.	32.0	38.0	40.0	44.0	44.0
“ “	125° C.	36.0	42.0	44.0	44.0	44.0
Shallow dish	125° C.	44.0	44.0	44.0	44.0	44.0

The sample in the square box that dried the quickest was in each case in the hottest part of the oven—directly over the flame.

			Percent Loss in Weight.						
			1 hr.	2 hrs.	3 hrs.	4 hrs.	5 hrs.	6 hrs.	7 hrs.
Square box	100-105° C.	14.0	22.0	28.0	34.0	38.0	42.0	44.0	
" "	100-105° C.	14.0	24.0	28.0	34.0	38.0	42.0	44.0	
Shallow dish	100-105° C.	40.0	46.0	46.0	48.0	48.0	48.0	48.0	
" "	125° C.	46.0	46.0	48.0	48.0	48.0	48.0	48.0	

The bottom of one of the square boxes was removed and replaced with fine wire gauze which allowed a circulation of air up through the bagasse, causing it to dry quicker:

			Per Cent. Loss in Weight.						
			1 hr.	2 hrs.	3 hrs.	4 hrs.	5 hrs.	6 hrs.	7 hrs.
Square box	100-105° C.	10.0	18.0	24.0	32.0	34.0	37.0	42.0	
" " screen bot-	100-105° C.	6.0	24.0	32.0	38.0	41.0	41.0	46.0	
tom,	100-105° C.	38.0	45.0	46.0	46.0	46.0	46.0	46.0	
Shallow dish	100-105° C.	46.0	46.0	46.0	46.0	46.0	46.0	46.0	
" "	125° C.	46.0	46.0	46.0	46.0	46.0	46.0	46.0	

The great advantage of a shallow container over a deep one for drying the bagasse samples is very evident from these results; and on account of the considerable length of time that it takes to completely dry the samples in deep containers it is not at all improbable that low results are being obtained in some cases where this form is being used.

#### EFFECT OF TEMPERATURE.

The results given above show a considerable difference in the length of time necessary to dry the samples at 125° C. and at 100-105° C. in both the shallow and deep form of container. There is an advantage therefore in drying at the higher rather than the lower temperature, if they give equally correct results. No deleterious effect from keeping the sample at 125° C. for seven hours was found. Other results have been obtained showing that some samples of bagasse can be heated for four hours at 140° C. without decomposition sufficient to affect practically the determination of the per cent. of moisture. Other samples, however, were more affected at this high temperature, so that it is not safe to heat above 125° C. All the tests were made in shallow dishes.

Time.	Temperature.	Percent Loss in Weight.
6½ hrs.	100-105° C.	47.0
2 "	125° C.	47.0
4 hrs.	100-105° C.	46.6
2 "	125° C.	46.4
4 "	125° C.	46.6

4 hrs.	100-105° C.	46.0
7 "	100-105° C.	46.6
2 "	125° C.	47.0
4 "	125° C.	47.0
7 hrs.	100-110° C.	49.0
2 "	110° C.	48.6
4 "	110-125° C.	49.0
4 hrs.	100-105° C.	47.0
7 "	100-105° C.	47.0
2 "	125° C.	47.0
4 "	125° C.	47.0
6 hrs.	100-105° C.	42.0
2½ hrs.	130° C.	42.0
3 hrs.	130° C.	42.0
4 hrs.	100-105° C.	46.6
7 "	100-105° C.	47.0
2 "	130° C.	47.0
4 "	130° C.	47.6
4 hrs.	100-105° C.	48.6
2 "	130° C.	49.0
4 "	130° C.	49.0
4 hrs.	100-105° C.	47.6
2 "	125° C.	48.0
4 "	130° C.	48.0
5 hrs.	100-105° C.	47.6
2 "	130° C.	47.6
5 "	130° C.	47.6
4 hrs.	100-105° C.	48.4
7 "	100-105° C.	48.4
2 "	140° C.	48.4
4 "	140° C.	48.4
4 hrs.	93° C. (Vacuum)	47.0
7 "	93° C. (Vacuum)	47.0
2 "	135° C.	47.0
4 "	135-140° C.	47.4

On account of the considerable length of time that it takes to completely dry some samples of bagasse in an ordinary air bath at temperatures as low as 100° to 105° C., there is a greater chance of failing to drive out all of the moisture by not heating long enough or high enough than of decomposing the bagasse by heating too high.

#### DRYING IN A VACUUM.

No advantage in the saving of time was found in drying the bagasse in a vacuum. According to the results obtained, the

shortest period of time that can be relied on for drying in a vacuum at 100° C. is three hours, which is the same length of time that it takes to dry the sample at 125° C. in an ordinary air bath.

				Percent Loss in Weight.
Air Bath,	2	hrs.,	135° C.	47.0
Vacuum Oven,	4	hrs.,	25 in., 93° C.	47.0
" "	7	" "	25 " 93° C.	47.0
Air Bath	3	hrs.,	125° C.	45.6
Vacuum Oven,	4	" "	27 in., 85° C.	45.6
" "	7	" "	27 " 85° C.	45.6
Air Bath,	3	hrs.,	125° C.	46.6
" "	7	" "	125° C.	47.0
Vacuum Oven,	3	" "	27½ in., 85° C.	46.6
" "	7	" "	27½ " 85° C.	47.0
Vacuum Oven,	2	hrs.,	26½ in., 100° C.	44.6
" "	2½	" "	26½ " 100° C.	46.0
" "	3	" "	26½ " 100° C.	46.0
" "	3½	" "	26½ " 100° C.	46.6
" "	4	" "	26½ " 100° C.	46.6
" "	5	" "	26½ " 100° C.	46.6
Vacuum Oven,	2	hrs.,	26 in., 100° C.	45.0
" "	3	" "	26 " 100° C.	45.6
" "	4	" "	26 " 100° C.	45.6
" "	5	" "	26 " 100° C.	45.6
Vacuum Oven,	1½	hrs.,	25-27 in., 100° C.	46.0
" "	2	" "	25-27 " 100° C.	47.0
" "	2½	" "	25-27 " 100° C.	47.0
" "	3	" "	25-27 " 100° C.	47.0
" "	3½	" "	25-27 " 100° C.	47.0
" "	4½	" "	25-27 " 100° C.	47.0
Vacuum Oven,	1	hr.,	27½ in., 100° C.	45.0
" "	1½	hrs.,	27½ " 100° C.	46.6
" "	2	" "	27½ " 100° C.	47.0
" "	2½	" "	27½ " 100° C.	47.0
" "	3	" "	27½ " 100° C.	47.0
Vacuum Oven,	1½	hrs.,	27½ in., 100° C.	44.0
" "	2	" "	27½ " 100° C.	44.0
" "	2½	" "	27½ " 100° C.	44.0
" "	3	" "	27½ " 100° C.	44.0
Vacuum Oven,	2½	hrs.,	28 in., 100° C.	44.6
" "	3	" "	28 " 100° C.	44.6
Vacuum Oven,	1	hr.,	28 in., 100° C.	33.0
" "	1½	hrs.,	28 " 100° C.	43.0
" "	2	" "	28 " 100° C.	47.0
" "	2½	" "	28 " 100° C.	47.0



METHOD SUGGESTED FOR THE SAMPLING AND THE DETERMINATION  
OF MOISTURE AND SUGAR IN BAGASSE.

Based on the results of all the foregoing experiments, the following method is suggested for the accurate sampling and determination of moisture and sugar in bagasse. *Sampling:* Once an hour take a sample of the bagasse immediately as it leaves the last mill, for the full length of the roller and the full depth of the bagasse blanket—about a kilogram in all. Mix thoroughly with the hands for half a minute in a deep vessel to prevent evaporation of the moisture. Discard about half of it, cover the vessel and take the rest to the laboratory. Chop the whole sample, a portion at a time, so that no piece over a quarter of an inch (6 mm.) in diameter is left.

*Determination of Moisture.*—Weigh out an amount of bagasse equal to 50 or 100 grams of the sample before chopping,\* on a shallow tray three-quarters of an inch (2 cm.) or less in depth. Heat in an air bath at 125° C. for three hours. Weigh quickly. Calculate the per cent. moisture from the loss in weight.

*Determination of Sugar.*—Weigh out an amount equal to 100 grams of the original bagasse into the inner digestion cup of the apparatus described on page 25. Add 500 cc. of hot water containing 5 cc. of a 5% solution of sodium carbonate. Press the bagasse down into the solution, and place the cup in the outside vessel containing boiling water. Digest for an hour, mixing the solution with the bagasse every 15 minutes by pressing down with the tamp, and using the latter for a cover for the digestion cup between times. Allow the mixture to cool a little and weigh. Filter as much of the solution as can be pressed out of the bagasse through cheesecloth into a flask, cool to laboratory temperature, pour 99 cc. of the solution into a 100 cc. flask; make up to 100 cc. with lead subacetate solution, filter and polarize in a 400 mm. tube. Find from Table I the polarization of the bagasse corresponding to the reading. If a 200 mm. tube is used, the reading is to be doubled.

If the special apparatus is not used for digesting the bagasse, weigh out the equivalent of 50 grams of the sample into a quart cup or pot with cover, add 500 cc. water containing 2 cc. of a 5% sodium carbonate solution, boil gently for an hour, stirring the solution thoroughly every 15 minutes and proceed as above, using Table II to find the polarization.

Tables I and II are calculated from the formula:

$$\frac{R(W - f)}{2 \times 3.8 \times 100} = \text{Polarization.}$$

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\* Determined by actual trial as described on page 8.

R = Polariscopes reading in a 400 mm. tube.

W = Weight of bagasse + solution, corresponding to 100 grams bagasse.

f = Per cent. fiber in bagasse.

The latter is taken as fifty, there being very little difference in the results with the usual variations in the fiber.

#### CONCLUSIONS.

1. The careful sampling is of more importance than any other part of the process of the analysis of bagasse.

2. No entirely satisfactory method of preserving bagasse has been found; it had therefore best be analyzed soon after it is collected.

3. The bagasse sample loses considerable moisture during the chopping, which should be taken account of in weighing samples for analysis.

4. In determining the polarization of bagasse by digestion in water, the digestion should be continued for an hour to insure a homogeneous diffusion of the solution through the bagasse.

5. No other dextro-rotatory substance than sugar is extracted or produced from bagasse from Hawaiian cane by boiling with water.

6. Bagasse cannot be sampled or analyzed accurately unless finely divided.

7. Two cubic centimeters of a 5% solution of sodium carbonate to 50 grams of bagasse was found to be the most convenient reagent to use in the water for digestion.

8. In digesting bagasse in water the solution should be mixed occasionally to insure a homogeneous diffusion.

9. No water should be added to the solution after digestion.

10. The same results are obtained by water digestion for 1 hour and by extraction with alcohol or water for  $1\frac{1}{2}$  to 2 hours.

11. A new method for determining the sugar in bagasse is suggested, by which a larger polariscopes reading is obtained, thereby reducing the error from this source.

12. Bagasse samples dry very much more quickly when spread out in a thin layer than in thick masses. A three-inch layer of bagasse cannot be depended upon to have lost all its moisture in seven hours at 100-105° C.

13. Bagasse can be dried safely at 125° C. in three hours.

14. Some samples of bagasse do not lose all their moisture when dried in a vacuum at 100° C. in less than three hours.

15. A method is suggested for the sampling, and the determination of sugar and moisture in bagasse, based on the results of the investigation.

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TABLE I.

POLARIZATION OF BAGASSE WITH 100 GRAM SAMPLE.

*Weight of Solution plus Bagasse.*

Polariscopes Reading, 400mm. Tube	450	455	460	465	470	475	480	485	490	495	500	505	510	515	520	525	530
3.0	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.9	1.9
3.1	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.9
10.0	5.2	5.3	5.4	5.4	5.5	5.6	5.6	5.7	5.8	5.8	5.9	6.0	6.0	6.1	6.2	6.2	6.3
10.1	5.3	5.4	5.4	5.5	5.6	5.6	5.7	5.8	5.8	5.9	6.0	6.0	6.1	6.2	6.2	6.3	6.4
10.2	5.4	5.4	5.5	5.6	5.6	5.7	5.8	5.8	5.9	6.0	6.0	6.1	6.2	6.2	6.3	6.4	6.4
10.3	5.4	5.5	5.5	5.6	5.7	5.7	5.8	5.9	5.9	6.0	6.1	6.1	6.2	6.3	6.4	6.4	6.5
10.4	5.5	5.5	5.6	5.7	5.7	5.8	5.9	5.9	6.0	6.1	6.1	6.2	6.3	6.3	6.4	6.5	6.5
10.5	5.5	5.6	5.6	5.7	5.8	5.9	5.9	6.0	6.1	6.1	6.2	6.3	6.3	6.4	6.5	6.5	6.6
10.6	5.6	5.6	5.7	5.8	5.8	5.9	6.0	6.0	6.1	6.2	6.3	6.3	6.4	6.5	6.5	6.6	6.7
10.7	5.6	5.7	5.7	5.8	5.9	6.0	6.0	6.1	6.2	6.2	6.3	6.4	6.4	6.5	6.6	6.7	6.7
10.8	5.7	5.7	5.8	5.9	6.0	6.0	6.1	6.2	6.2	6.3	6.4	6.4	6.5	6.6	6.7	6.7	6.8
10.9	5.7	5.8	5.9	5.9	6.0	6.1	6.1	6.2	6.3	6.4	6.4	6.5	6.6	6.7	6.7	6.8	6.9
11.0	5.8	5.8	5.9	6.0	6.1	6.1	6.2	6.3	6.3	6.4	6.5	6.5	6.6	6.7	6.8	6.9	6.9





# HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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**REPORT OF WORK  
OF THE  
EXPERIMENT STATION  
OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION**

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**Sulphate Scale in Evaporators.**

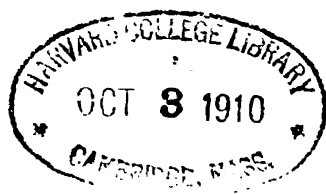
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**By S. S. PECK**

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**HONOLULU, HAWAII,  
1910.**





*Ex Libris*

## LETTER OF TRANSMITTAL.

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To the Experiment Station Committee of the  
Hawaiian Sugar Planters' Association,  
Honolulu, Hawaii.

Dear Sirs:—I herewith submit for publication, as Bulletin No. 33 of the Agricultural and Chemical Series, an article by Mr. S. S. Peck, Chemist, entitled: "Sulphate Scale in Evaporators."

Yours very truly,

C. F. ECKART,

Director.

Honolulu, Hawaii, August 3, 1910.



## SULPHATE SCALE IN EVAPORATORS.

BY S. S. PECK.

In Bulletin 21, Agricultural and Chemical Series, of this Station, dealing with incrustations on tubes of evaporators, the distinction was made of three kinds of scale; viz., silicate, sulphate, and phosphate. Suggestions were made whereby the trouble due to the last could be largely mitigated. This bulletin will treat of investigations into a method whereby the amount of sulphate scale can be considerably diminished.

During the early part of the season of 1910, one of the factories on these islands experienced considerable trouble on account of excessive scale formation, the work of the mill being, on that account, seriously affected. Samples of the scales from the three cells of the evaporating apparatus and a sample of the juice from which the scales originated were forwarded to this Station for analysis and experiment in treatment of the juice. The incrustations from the first and second bodies were of a brown to black color and of a loose, friable nature; that from the third was almost white in color, of a hard, dense texture and laminate structure, which are characteristics we have learned to associate with sulphate scale. The analyses of these scales gave results as follows:

### Analysis of Scale from Three Cells of Triple Effect.

	1st Body.	2d Body.	3d Body.
Mineral Matter.....	66.95	59.06	72.90
Organic Matter.....	33.05	40.94	27.10

### Analysis of Mineral Matter.

	1st Body.	2d Body.	3d Body.
Silica .....	1.64	24.33	2.06
Iron and Aluminum Oxides.....	2.89	1.43	.13
Lime .....	45.40	35.93	40.87
Magnesia .....	1.72	3.88	.37
Phosphoric Acid.....	40.10	20.58	1.81
Sulphuric Acid.....	3.74	9.59	53.59

The scale in the first body is a phosphate scale; that in the third, a sulphate; and that in the second, intermediate in these respects, but considerably higher in silica. The principal trouble in the factory from which these scales came arose in the third body, where the incrustation consisted of 66.4 per cent of calcium sulphate, this salt composing 91.1 per cent of the mineral matter. The sulphate, as also the phosphate of calcium are as stated by Ware,\* very bad conductors of heat; "When only one millimeter (one twenty-fifth of an inch) in thickness on the tubes of an effect, they can destroy the evaporating capacity of the evaporators." Since as much as 700 pounds of scale were removed from the tubes of the third effect after a week's operation, it is easy to understand the difficulty under which the factory was operating.

One possible means by which sulphuric acid could be introduced into the mill juice is through the lime used for clarification. Analysis of the lime, a sample of which accompanied the scale samples, showed it to be of a superior quality, containing but .02 per cent sulphuric acid. The juice on analysis gave the following results:

Brix .....	16.68			
Polarization .....	13.25			
Purity .....	79.45			
Total Ash.....	4.502	grams	per	liter
Insoluble Ash.....	2.518	"	"	"
Soluble Ash.....	1.984	"	"	"
Lime .....	.620	"	"	"
Phosphoric Acid.....	.651	"	"	"
Sulphuric Acid.....	.974	"	"	"
Silica .....	.434	"	"	"
Iron and Aluminum Oxides...	.054	"	"	"

In Bulletin 21 it was shown, that basing calculations on the solubility of calcium sulphate in sucrose and water, a juice containing .339 gram of that salt per liter might be expected to deposit a sulphate scale. In this case we have to handle a juice containing over two and a half times as much of this material, and it might reasonably be expected that such a juice would deposit that much more scale, provided sufficient lime is present to combine with the sulphuric acid.

In addition to the raw juice sample, one of clarified juice was also sent. This juice gave the following analysis, the results be-

\*Ware's "Beet-Sugar Manufacture and Refining," Vol II.

ing figured to the same density as the raw juice, and reported as grams per liter.

Total ash.....	4.238	Lime .....	.699
Insoluble ash.....	1.030	Phosphoric acid..	.667
Soluble ash.....	3.208	Sulphuric acid...	1.453

This analysis explains fully the cause of the formation of large quantities of sulphate scale. In such a juice, after combining the phosphoric acid with lime, there is left sufficient of the latter to form 1.5 grams of calcium sulphate in a liter of juice. This amount is evidently considerably in excess of that which obtains in juices, as it approaches the saturation point of calcium sulphate in sugar and salt solutions, which is given in Bulletin 21 as 1.883 grams in a liter of water containing sugar and potassium chloride, at 100° C. If such an extreme amount occurred in the juice, we would expect to find considerable scale containing a fairly high proportion of calcium sulphate in the first body of the effect; on the contrary, in practice the scale formation is not very great in this cell, and the incrustation formed contains but a small percentage of calcium sulphate. If it is presumed that the clarified juice contains one gram of calcium sulphate per liter, the amount of scale possible from the evaporation of such a juice may be roughly approximated as follows: 400,000 gallons of juice, which is the average weekly work of the factory in question, containing one gram of calcium sulphate per liter, will have in solution 3331 pounds of that material. The average of nine molasses from the Island of Hawaii gives an analysis as follows:\*

Density .....	1.464
Brix .....	87.0
Lime .....	1.334 percent
Sulphuric Acid.....	1.431   “
Phosphoric Acid.....	.273   “

After combining the phosphoric acid with lime, giving 8.73 grams lime phosphate per liter, there is enough of the lime left to combine with all of the sulphuric acid, and would indicate 2.433 grams of the sulphate of calcium in 100 grams of molasses, or 35.62 grams per liter. From the annual synopsis of mill data of 1909 it may be assumed (1) that there are 30 gallons of molasses produced per ton of manufactured sugar: (2) that it takes

\*Bulletin 18, Experiment Station, H. S. P. A., Agricultural and Chemical Series.

8.5 tons of cane (Yellow Caledonia) to produce a ton of sugar; and (3) that for each ton of cane there enters into manufacture one ton of clarified juice. From these data it is calculated that 400,000 gallons of juice of 15 Brix and weighing 1776 tons would produce 6270 gallons of molasses which would contain, in solution and suspension, at the rate of 35.62 grams per liter, 1860 pounds of lime sulphate, leaving 1471 pounds to be deposited as scale in the effects. The mill in question reports an actual removal of 700 pounds of scale, which by analysis gives 464 pounds of lime sulphate from the third effect; whilst both the other bodies contained a further quantity of that material, but in greatly inferior amounts.

Another interesting point is a statement in the communication of the manager of the mill that when more lime was added more scale was formed. The table of analysis of the clarified juice explains this. There is lime enough present to combine with only .885 gram of the sulphuric anhydride present in a liter of the juice, leaving .568 gram combined with the magnesium and alkali salts. Consequently if more lime is added, more lime sulphate will be produced.

Two methods suggest themselves for correcting the trouble due to the formation of sulphate scale, the use of barium salts or sodium carbonate in the juice during clarification. The first treatment removes the sulphuric acid by precipitation from the juice as sulphate of barium; but the method is open to grave objections on account of the poisonous nature of the salts of barium and the danger of accidentally introducing them into products intended for human consumption. The addition of sodium carbonate in conjunction with lime to a juice may be expected to have one of two actions. 1°. If not enough lime is supplied the juice to produce an alkaline or neutral reaction, considerable of the phosphoric acid would not be removed, although there is sufficient lime to combine with all the phosphoric acid remaining. This is due partly to the solubility of phosphate of lime in sugar and salt solution,\* but more largely to the increased solubility of lime phosphate in an acid liquid. If to such a liquid sufficient sodium carbonate is added to produce alkalinity, the lime phosphate would be largely or almost entirely rendered insoluble and removed from the juice in the clarifier settlings. 2°. If lime is added in sufficient quantity to produce the alkalinity necessary for the removal of the larger proportion of the phosphates, there is always then an excess of lime sufficient to produce trouble in juices similar to

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\*See Bulletin 21 Experiment Station, H. S. P. A., Agricultural and Chemical Series.

that under consideration, i. e., the formation of lime sulphate. When sodium carbonate is added to a solution of the lime sulphate, a double reaction takes place, calcium carbonate and sodium sulphate resulting. When juice with lime in excess for clarification and a high content of sulphuric acid is treated with the sodium carbonate, the insoluble calcium carbonate will settle out in the clarifiers, only an unimportant amount being retained in solution in the juice. The sodium sulphate, being very soluble, will continue through the course of manufacture into the final molasses. Whilst the unnecessary introduction of foreign soluble salts into the juice is usually to be avoided, it is not thought that sodium sulphate will have any serious effects. Koehler is quoted as finding that "certain salts, notably sulphate of soda, chloride of calcium, and sulphate of magnesia even possess the property of causing the precipitation of a considerable proportion of the sugar in solution in the liquid."\*

The use of sodium carbonate in addition to lime has been advised, although not as a corrective for scale. Geerligs writes:† "It happens in many cases that cane juice has an acid reaction, although sufficient lime has been added to precipitate all impurities. It is not advisable to evaporate such acid juices, and they should therefore be neutralized, which may be effected during defecation or afterwards on elimination of the settled juice. Until a few years ago, lime was exclusively used for this neutralization, but as lime salts always cause more trouble during the subsequent operations than soda salts, soda has been adopted for this purpose. For purifying purposes lime is of course, the indispensable agent."

The effect of sodium carbonate and sodium bicarbonate as additions to lime as clarifying media was studied with the raw juice accompanying the scale. Two hundred cubic centimeter lots were clarified with lime alone and with lime and soda salts. The lime was made into a milk, which was found by titration to contain .093 gram of calcium oxide in 10 cc. The sodium salts were dissolved in distilled water to normal solutions, 10 cc. of the carbonate solution therefore containing .53 gram of the dry salt and the bicarbonate .42 gram. For convenience of reference and comparison all the results and quantities have been calculated to a liter basis. The following is the description of the tests:

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\*The Sugar Cane, April, 1907.

†Cane Sugar and its Manufacture, H. C. Prinsen Geerligs.



Number	Clarifying Agent per Liter			Reaction	Settled
	Milk of Lime	Normal Sodium Carbonate	Normal Sodium Bicarbonate		
1.....	25 cc.	0	0	acid	slowly
2.....	25 cc.	10 cc.	0	alkaline	fairly
3.....	25 cc.	25 cc.	0	"	quickly
4.....	25 cc.	25 cc.	0	"	"
5.....	25 cc.	0	25 cc.	"	slowly
6.....	50 cc.	0	0	"	quickly
7.....	50 cc.	10 cc.	0	"	"
8.....	50 cc.	25 cc.	0	"	"
9.....	50 cc.	0	25 cc.	"	"
10.....	50 cc.	0	25 cc.	"	poorly

It was found that 5 cc. of the milk of lime to 200 cc. juice left the juice with an acid reaction, whilst 10 cc. made it distinctly alkaline, both to litmus and phenolphthalein. The juice was limed cold, and the soda salts added at once with the exception of tests 4 and 10. The juice was heated and allowed to boil exactly two minutes. In the cases of 4 and 10, the juice after liming was brought to a boil, the soda salt added, and the boiling continued for two minutes. The only difference observed in these two treatments was that the rate of settling in 10 where the bicarbonate was added after the limed juice was at the boiling temperature was much slower than when both the lime and bicarbonate were added in the cold. Between 3 and 4 no difference in settling was observed; and as will appear from the analytical results which follow, in neither instance was there any noticeable effect produced in regard to mineral matter removed from the juice.

After having boiled the requisite time, the precipitate was allowed to settle, and observations made as to the rate thereof. It was then filtered through ashless paper, and the filtrate cooled and analyzed. The residue was transferred to the paper with the least possible amount of water required for that purpose, dried, weighed, and then incinerated. The weight of the ash gave the amount of mineral matter removed by each method of clarification.

The juices after cooling were first polarized and the density determined by pycnometer. In the following table are given the Brix, (found from the density), the sucrose, and purity.

TABLE I.

Number	Brix	Sucrose	Purity
1.....	16.68	13.3	79.73
2.....	17.44	14.0	80.28
3.....	16.85	13.4	79.52
4.....	16.84	13.5	80.16
5.....	16.35	13.2	80.73
6.....	16.55	13.3	80.36
7.....	16.15	13.0	80.49
8.....	16.31	13.0	79.70
9.....	16.18	13.0	80.34
10.....	16.02	12.9	80.52

The extreme variation in purity is 1.21, test 5 having the highest, 80.73, and test 3 the lowest, 79.52, practically the same as in the original material. As will be seen later, the purity results have no relationship with the amounts of material removed, and we are inclined to believe that the irregularities are partly accidental, due to the varying length of time necessary for the filtration of the individual tests.

The amounts of material, total, organic, and mineral removed from a liter of juice, are given in Table II. It will be remembered that these residues were washed only by the small amount of water necessary to transfer the precipitates to the paper, and the organic matter therefore represents a certain amount of sugars and soluble non-sugars.

TABLE II.

Material Removed from One Liter of Juice in Grams.

Number	Total	Organic	Mineral
1.....	6.6525	5.9810	.6715
2.....	8.3125	7.0715	1.2410
3.....	8.4335	6.7865	1.6470
4.....	10.5950	8.7700	1.8250
5.....	10.0515	8.6535	1.3980
6.....	7.3405	6.0565	1.2840
7.....	10.1300	8.1315	1.9985
8.....	9.0900	7.1385	1.9515
9.....	9.8985	8.0830	1.8155
10.....	10.1640	8.5465	1.6175

By comparing test 1 with tests 2, 3, 4, and 5, where 25 cc. of milk of lime were added; and test 6 with 7, 8, 9 and 10, where twice the lime was used, it will be seen that the addition of soda to the lime increased the amount of both the mineral and organic matter removed from the juice. Increasing the amount of soda carbonate in the 25 cc. lime series from 10 cc. to 25 cc. augmented the quantity of mineral matter removed. In the 50 cc. series, on the contrary, such an increase caused a slight drop. Slight irregularities in the results, however, are not to be considered as actual differences for two reasons: 1°, the juice, being raw, unfiltered juice, was full of suspended impurities, and in transferring the 200 cc. to each beaker for clarification, the amount of such suspended matter in each test would not be absolutely the same; and 2°, the lime was added from a 5 or 10 cc. pipette, and although the stock milk of lime was thoroughly shaken each time before being drawn into the pipette, there was always a possibility of slight differences in the amount of lime added.

The clarified juices were analyzed for total and insoluble ash, phosphoric acid, and lime. Table III contains these results reported in grams per liter, all figures being calculated to the density of the original juice. The analysis of this is repeated to facilitate comparison.

TABLE III.  
Mineral Matter in Juices, Grams per Liter.

Number	Ash			Phos. Acid	Lime
	Total	Insoluble	Soluble		
Original.....	4.502	2.518	1.984	.651	.620
1.....	4.445	1.979	2.466	.513	.647
2.....	3.986	1.463	2.523	.206	.451
3.....	4.514	.966	3.548	.094	.240
4.....	4.505	.917	3.588	.079	.234
5.....	4.430	1.271	3.159	.237	.437
6.....	3.805	1.338	2.467	.243	.496
7.....	4.402	.884	3.518	.080	.244
8.....	4.471	.827	3.644	.042	.290
9.....	4.152	.961	3.191	.210	.454
10.....	4.515	1.177	3.338	.205	.471

The addition of either sodium carbonate or bicarbonate had a distinct effect in reducing the insoluble ash, phosphoric acid, and lime. As concluded from the residue results, the increase of the amount of sodium carbonate had a more decided result where an amount of lime insufficient to produce alkalinity was used. This is due to the fact, as has already been mentioned, that the acidity of the juice prevented the precipitation of the phosphate of lime; on this being corrected by the alkaline carbonate, a considerably larger proportion of both phosphoric acid and lime was removed. Aside from the lime, the sodium carbonate itself has a clearing action in this respect, as will be shown in a second series of experiments. Where the lime was in sufficient quantity to produce an alkaline juice, the decrease of the amount of insoluble ash and phosphoric acid was proportionally less, but still showed a very effective result.

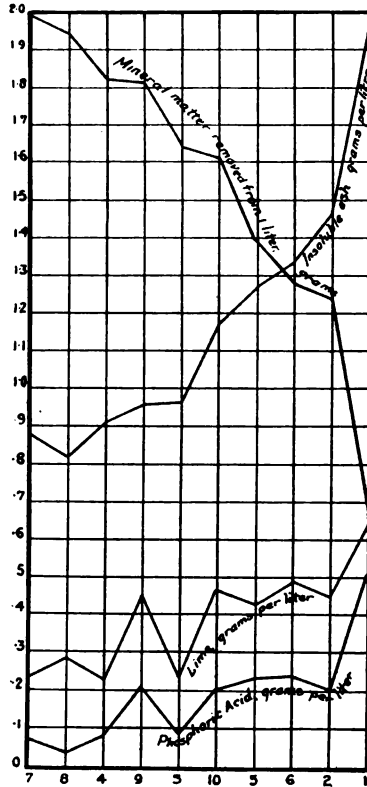
In Table IV, the results are collected to show the relationship existing between insoluble ash, lime, and phosphoric acid remaining in the juice, on the one hand; and, mineral matter removed in the residue, on the other hand, the latter being the equivalent of the filter press work of a factory. The data are arranged according to the descending amount of mineral matter removed.

TABLE IV.

Comparison of Total Mineral Matter Removed and Ash Remaining.

Number	Mineral Matter Removed from 1000 cc., Grams	Grams per Liter		
		Insoluble Ash	Phos. Acid	Lime
7.....	1.9985	.884	.080	.244
8.....	1.9515	.827	.042	.290
4.....	1.8250	.917	.079	.234
9.....	1.8155	.961	.210	.454
3.....	1.6470	.966	.094	.240
10.....	1.6175	1.177	.205	.471
5.....	1.3980	1.271	.237	.437
6.....	1.2840	1.338	.243	.496
2.....	1.2410	1.463	.206	.451
1.....	.6715	1.979	.513	.647

As shown by this table and the accompanying diagram, a drop in the amount of mineral matter removed is accompanied by an increase in the amount of insoluble ash remaining in the juice. With the exception of number 9, the phosphoric acid and lime content drops with that of insoluble ash. Sodium carbonate had a considerably better effect in the direction of removing the scale



forming elements than did the bicarbonate. It will be noticed, too, that the juice of 6 contained less lime than that of 1, although twice as much was used in clarification in the first instance as in the second. These results are similar to those obtained in our previous work on evaporator scale.\* The precipitates removed

\*Loc. cit.

consist almost entirely of silica, lime, magnesia, and phosphoric acid, as is shown in Table V. The arrangement in this table is the same as in Table IV, according to the descending weights of mineral matter removed.

TABLE V.

Mineral Matter Removed from One Liter Juice, in Grams.

Number	Silica	Iron and Aluminium Oxides	Lime	Magnesia	Phos. Acid	Sulph. Acid
7.....	.4340	.0565	.7450	.0770	.6060	.0290
8.....	.4345	.0550	.7150	.0905	.6380	.0250
4.....	.5130	.0590	.4950	.1835	.5440	.0235
9.....	.4310	.0465	.5925	.1430	.4615	.0190
3.....	.4155	.0515	.4725	.1720	.5295	.0165
10.....	.4330	.0500	.4950	.1095	.4655	.0230
5.....	.4940	.0565	.3500	.1060	.3700	.0195
6.....	.4090	.0575	.3725	.0805	.3500	.0295
2.....	.5040	.0565	.2900	.0905	.2965	.0210
1.....	.4055	.0550	.0975	.0345	.0605	.0200

Practically all the silica and oxides of iron and aluminum were found in the precipitate from clarification, the raw juice containing .434 and .054 gram per liter respectively. A small proportion of the sulphuric acid, varying from a maximum of 3.03 to a minimum of 1.69 percent of the original, was removed. The variations are irregular and doubtless accidental. The lime and phosphoric content changed almost together, a drop in the one implying a drop in the other. The sodium bicarbonate was not nearly so effective as the carbonate in removing the lime and phosphoric acid, when added in molecular equivalents. This was of course to be expected, as the bicarbonate has but half the neutralizing effect on acids that the carbonate possesses. The figures for magnesia present unexplicable differences. Whilst any correction for acidity, whether by doubling the lime or introducing an alkaline salt made the amount removed in the sediment increase by over a hundred percent, there is no regularity in this increase which will point to the reaction or reactions causing it. Tests 3 and 4 with 25 cc. each of milk of lime and sodium carbonate solution removed about .18 gram of magnesia from a liter; whilst test 8, with double the lime and the same quantity of sodium carbonate, removed but half the quantity. Again, tests 9 and 10, with the same lime as 8, but with sodium bicarbonate, had more

magnesia removed than was taken out in the case of 8. Increasing the amount of sodium carbonate, in any particular case increased the amount of magnesia removed, as may be seen by comparing test 2 with 3 and 4, or test 7 with 8. At the same time in test 6, with 50 cc. of lime and no sodium carbonate, more magnesia was removed than in test 7 with 10 cc. of normal carbonate solution and but slightly less than in 8 where 25 cc. of the carbonate solution were added. It may be reasonably explained by the probability that in the presence of a large excess of lime, most of the phosphoric acid is precipitated as the lime compound, whilst with a less amount present and the desired alkalinity produced by alkaline carbonates, magnesium phosphate forms a considerable proportion of the precipitated residue.

The action of the added carbonates can be seen more clearly when exhibited as percentages of material removed from that in the juice. Using the analysis of the ash in the juice as the basis, with the exception of the last item, Tables VI and VII show this relationship.

TABLE VI.

Juices clarified with 25 cc. milk of lime per liter, the alkalinity being produced by alkaline carbonates.

	1	2	5	3	4
Pct. of phosphoric acid removed	21.2	68.3	63.6	85.6	87.9
" lime	"	...*	27.3	29.5	61.3
" insoluble ash	"	21.4	41.9	49.5	61.6
Prop't'n of mineral matter	"	1	1.85	2.08	2.45

In this table and the following, no account is taken of the lime used in clarification. The figures for lime removed are based on that in the juices before and after clarification.

TABLE VII.

Juice Clarified with 50 cc. Milk of Lime.

	6	10	9	8	7
Pct. of phosphoric acid removed	62.7	68.5	67.7	93.5	87.7
" lime	"	20.0	24.0	26.8	53.2
" insoluble ash	"	46.8	53.3	61.8	67.2
Prop't'n of mineral matter	"	1	1.26	1.41	1.52

These tables display in a convenient form the relative effects of the carbonate and bicarbonate of soda in relieving the juice of

\*Lime higher than in original.

scale forming elements. A comparison of 2 and 5 in Table VI shows that one part of the carbonate was as effective as two parts of bicarbonate. From Table VII it is seen that one part of carbonate was over ten percent better than two parts of the bicarbonate as regards the removal of phosphoric acid, and over a hundred percent more efficient as regards that of lime. The best results with respect to lime were obtained from test 4, where there was 62.3 percent less than there was originally in the juice. The corresponding test with the same quantity of sodium carbonate and twice the lime, number 8, removed more phosphoric acid but less lime, more of this element being present from the increased amount used in clarification. On the whole, the proportion used in test 7, viz., 50 cc. milk of lime and 10 cc. carbonate solution per liter, equivalent to 3.9 pounds of lime and 4.4 pounds of dry carbonate of soda per 1000 gallons, gave the most satisfactory results. Using the same method of calculation as before, 400,000 gallons of juices clarified by the above methods would contain the following quantities of phosphate and sulphate of lime.

TABLE VIII.

Pounds of Phosphate and Sulphate of Lime in 400,000 Gallons Juice.

	1	2	3	4	5
Phosphate .....	3732	1499	684	574	1723
Sulphate .....	323	1674	1043	1140	1270
Total .....	4055	3173	1727	1714	2993
	6	7	8	9	10
Phosphate .....	1767	582	305	1527	1491
Sulphate .....	1690	1205	1941	1666	1844
Total .....	3457	1787	2246	3193	3335

As the phosphate of lime is extremely insoluble in water or sugar and salt solutions, all the phosphoric acid has been combined, with lime, and the surplus of the last with sulphuric acid, although it is certain that a part of the phosphoric acid will combine with magnesia. However, this element has been found from numerous analyses of scales to be present there to a much smaller extent than lime, and as the consideration of any magnesia combination would involve much uncertain calculation and assumption, it has been neglected.

Test 1 in particular, and tests 2, 5, 6, 9 and 10 give strong probabilities of a large formation of phosphate scale. Tests 3 and 4



give good results, but require the use of a considerable quantity of sodium carbonate. At about half the cost of clarifying reagents in 7, almost as good results are obtained. Since a waste molasses from 400,000 gallons of juice may contain approximately up to 1860 pounds of lime sulphate and 456 pounds lime phosphate, the juices as clarified according to the scheme proposed should give little scale trouble.

As somewhat confirming the expectation of the cessation of scale trouble with juices of composition of those in tests 3, 4, 7, or 8, the analysis of the clarified juice from another mill, where very little annoyance is caused by scale, is given below, the figures being calculated to the density of the juices already reported.

Total ash.....	3.010	grams	per	liter
Insoluble ash.....	.952	"	"	"
Soluble ash.....	2.058	"	"	"
Phosphoric acid.....	.046	"	"	"
Sulphuric acid.....	.346	"	"	"
Lime .....	.685	"	"	"

In this case there is more than enough lime to combine with all the sulphuric acid; 400,000 gallons of such a juice would contain 333 pounds of the phosphate and 1959 pounds of the sulphate of lime. The content in the latter element is more than that found in the juices clarified with lime and sodium carbonate, but is not in sufficient quantity to form a troublesome amount of scale; it approximates the amount estimated as being possible to be retained by the molasses.

In the particular case of the mill furnishing the scale samples, the juice was being clarified by the addition of 4.4 pounds of lime per 1000 gallons of juice. With the use of soda, the cost of clarification will be materially increased, although it is possible that, depending on the nature of the juice, even considerably less than the minimum used in these experiments will be sufficient to mitigate the scale troubles. When using 3.9 pounds of lime and 4.4 pounds of carbonate of soda to 1000 gallons juice, the cost of handling 400,000 gallons would be raised from \$17.60, where 4.4 pounds of lime alone were used, to \$50.80, the lime and soda being taken as costing one and two cents per pound respectively.

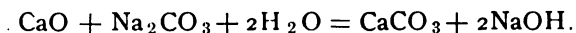
## SECOND SERIES.

A second series was carried out with more attention to the accuracy of measuring out the lime used in clarification and with the precaution of filtering the juice previous to working with it.

The juice was obtained from Yellow Caledonia cane grown on the grounds of the Experiment Station. It was filtered by means of a centrifugal, the sides of the basket being lined with paper pulp; in this way a juice absolutely free of suspended matter was obtained. The analysis of the filtered juice gave the following figures.

Brix .....	20.00			
Polarization .....	17.95			
Purity .....	89.75			
Total ash.....	6.168	grams per liter		
Insoluble ash.....	3.438	"	"	"
Soluble ash.....	2.730	"	"	"
Silica .....	.120	"	"	"
Iron and Aluminum oxides....	.044	"	"	"
Lime .....	.652	"	"	"
Magnesia .....	.720	"	"	"
Potash .....	1.684	"	"	"
Phosphoric acid.....	1.365	"	"	"
Sulphuric acid.....	.700	"	"	"
Chlorine .....	.476	"	"	"

Four hundred cubic centimeter portions of the juice were clarified with chemically pure lime in quantities varying from .25 to 1.25 grams per liter. The lime was found to be partially hydrated, containing actually 93 per cent of calcium oxide. According to the equation,



each part of lime, if 100 percent pure, would require for its conversion into carbonate 1.9 parts of sodium carbonate. Accordingly, in these experiments, this proportion was used, although on account of the lime being only 93 percent pure, the sodium carbonate was slightly in excess of the required amount.

As in the first series, the juice with the lime or lime and sodium carbonate added in the cold, was brought to a boil and boiled for two minutes. The lime was weighed out for each experiment and slaked in the least amount of water necessary. The sodium carbonate was prepared in solution, so that each 10 cc. of solution contained .19 gram of this salt. After settling, the clarified

juice was filtered under pressure and the filtrate cooled and analyzed. The residue was washed on the filter paper until all the soluble matter was removed, dried at 100° and weighed; then incinerated and the weight of mineral matter obtained.

The several methods of treatment were as follows, all figures being estimated on the liter basis, as in the first series.

Number	93 percent. Lime, Grams	Sodium Carbonate Grams	Reaction	Settled	Filtered
1.....	.25	0	acid	poorly	slowly
2.....	.50	0	acid	fairly	"
3.....	.75	0	neutral	quickly	quickly
4.....	1.25	0	alkaline	very quickly	"
5.....	.25	.475	acid	quickly	"
6.....	.25	.950	alkaline	very quickly	"
7.....	.50	.475	"	"	"
8.....	.50	.950	"	"	"
9.....	.75	.475	"	"	"
10.....	.75	1.425	"	"	"
11.....	1.25	2.375	"	"	"
12.....	0	1.425	"	poorly	slowly

Table IX gives the analyses of the juices. It will be noticed that in many instances there was a considerable drop in density. This is due to the fact that the sodium carbonate was added in solution, 10 cc. of this solution containing .19 gram of the salt.

TABLE IX.

Number	Brix	Sucrose	Purity
Original.....	20.0	17.95	89.75
1.....	21.6	19.7	91.20
2.....	21.1	19.0	90.05
3.....	20.8	18.7	89.90
4.....	21.2	19.6	92.45
5.....	20.9	19.2	91.86
6.....	20.0	18.3	91.50
7.....	20.4	18.9	92.65
8.....	19.6	18.1	92.35
9.....	20.6	19.1	92.71
10.....	19.1	17.6	92.15
11.....	19.3	17.8	92.23
12.....	19.6	17.8	90.82

The addition of sodium carbonate alone to the juice increased the purity 1.07 degrees. The addition thereof to limed juices in all cases increased the purity, the differences varying from .30 to 2.77 degrees.

The weights of the organic and mineral matter removed from a liter of juice, thoroughly washed of all sugars and other soluble matter, are given in Table X.

TABLE X.  
Material Removed from a Liter of Juice in Grams.

Number	Total	Organic	Mineral
1.....	2.398	1.940	.458
2.....	2.803	1.756	1.047
3.....	4.038	2.212	1.826
4.....	5.401	2.520	2.881
5.....	2.877	1.755	1.122
6.....	3.454	1.897	1.557
7.....	3.696	1.930	1.766
8.....	4.200	2.038	2.162
9.....	4.874	2.657	2.217
10.....	5.827	2.959	2.868
11.....	6.229	2.833	3.396
12.....	4.306	3.077	1.229

Increasing the lime produced a regular increase in the total and mineral matter removed. When sodium carbonate was also supplied, there was a regular gain in the amount of impurities eliminated from the juice; whilst sodium carbonate alone equivalent to .75 gram of lime rendered more organic matter insoluble than did any of the lime or lime and soda treatments. As with the first series, no comparison can be drawn between these results and the purity figures.

For the purpose of obtaining the ashes of the juices for analysis, a different *modus operandi* was adopted than in the first series, looking towards securing larger quantities of ash and lessening the chance of error. After filtration and cooling, measured quantities of each lot were pipetted into Erlenmeyer flasks, the alkaline juices acidulated with sulphuric acid, a few drops of an active yeast culture introduced, stoppered with cotton, and allowed to ferment. After fermentation was complete, it was an easy matter to incinerate as much as 100 cc. of a sample, as there was but little organic matter present after the disappearance of the

sugars. In the first series, the juices were treated with formaldehyde for the purpose of preservation before forwarding to the Station, so that the destruction of the sugars by fermentation was not possible. The analyses of the juices, given in grams per liter, and figured to the density of the original juice, will be found in Table XI. The determinations of silica and the oxides of iron and aluminum are not included, not being germane to the subject.

TABLE XI.  
Mineral Matter in Juices, Grams per Liter.

Number	Ash			Phos. Acid	Lime	Magnesia
	Total	Insoluble	Soluble			
Original.....	6.168	3.438	2.730	1.365	.652	.720
1.....	6.215	3.100	3.115	1.222	.691	.635
2.....	5.675	2.611	3.064	.896	.656	.584
3.....	5.250	1.932	3.318	.516	.535	.547
4.....	4.220	.915	3.305	.102	.500	.460
5.....	6.171	1.966	4.205	.835	.603	.588
6.....	5.318	.892	4.426	.638	.310	.514
7.....	5.633	1.470	4.163	.554	.382	.512
8.....	5.134	.839	4.295	.283	.229	.502
9.....	5.221	1.234	3.987	.340	.394	.511
10.....	5.819	.576	5.243	.072	.170	.371
11.....	6.471	.626	5.845	.033	.236	.422
12.....	6.345	1.094	5.251	.821	.208	.535

As in the first series, the sodium carbonate removed considerable amounts of phosphoric acid and lime, at the same time decreasing the amount of insoluble ash in the juice. The same effect was produced by increasing the amount of lime, but in that case there was still enough left of that element to produce trouble in the effects, given the presence of sufficient sulphuric acid to combine with it. Lime alone decreased the phosphoric acid content from 1.365 grams per liter to .102 gram per liter, or a removal of 92.5 percent, where an excess was added; at the same time there was 23.3 percent less lime left. In fact, as the lime added to the juice was increased two-, three-, or five-fold, the amount left in the clarified product decreased. These results

are similar to those obtained in our previous work on scale,\* where a juice originally containing .263 gram lime per liter, contained .274, .249, and .217 gram respectively after an acid, neutral, and alkaline clarification. They are at variance with the opinion expressed by Geerligs† that "the proportion of lime pre-existing in the juice and of that which has neutralized the free acid in the juice;" but are supported by quotations from two experimenters in Ware‡ as follows: "According to Grimmer calcic salts are partly eliminated from juices when lime is used in excess and basic lime salts are formed. Malander points out that excessively limed juices contain fewer calcic salts than those submitted to a moderate liming." The phosphoric acid content drops regularly with the increase of lime used in clarification. As with our previous work in connection with the removal of phosphoric acid, it is conclusively shown that phosphoric acid is held in solution in the juices, since all the juices were passed through filter paper; and that as the lime proportion was increased, the phosphoric acid content diminished. The reason that juices treated by the carbonation methods contain so little phosphoric acid is due not so much to the fact that they have been filtered, but to the fact that they have been heavily limed and the phosphoric acid precipitated as lime phosphate.

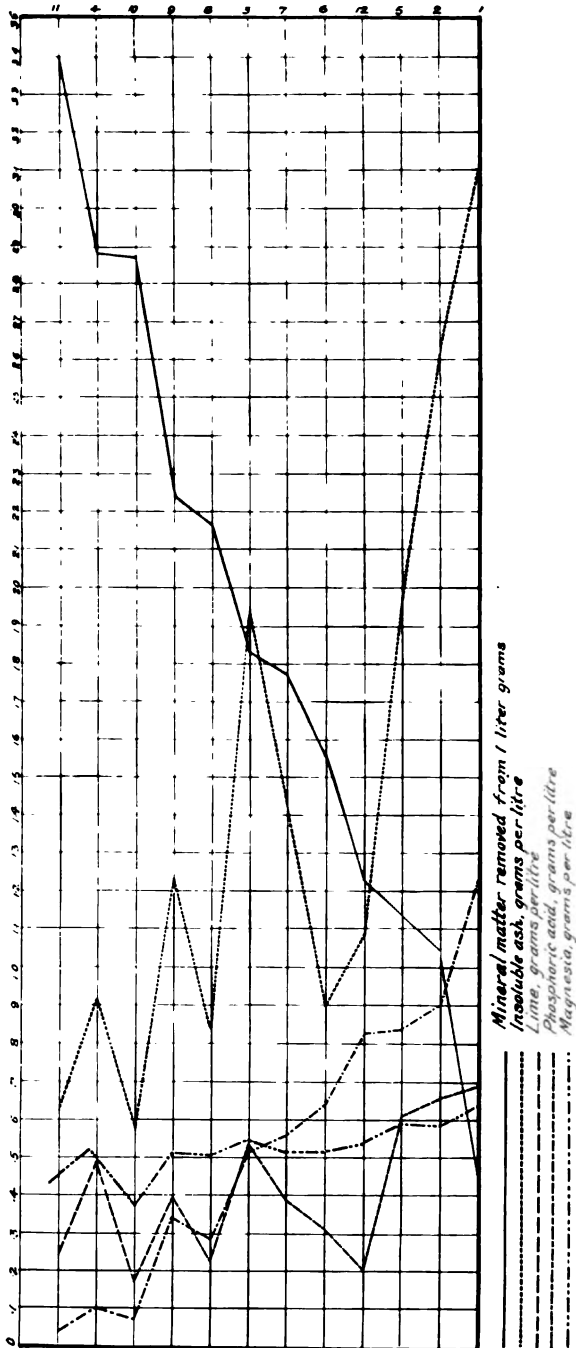
If the lime treatment is supplemented with that of sodium carbonate, the phosphoric acid drops down to .033 gram per liter, equivalent to a removal of 97.6 percent of that originally contained, and the lime content dropped to .236 gram per liter, a lessening of 63.8 per cent in this respect. The sodium carbonate alone was of considerable effect, removing 39.8 percent of the phosphoric acid and 68.1 percent of the lime. The best effect as regards lime content was observed in test 10, where .75 gram lime and 1.425 grams sodium carbonate were used, the diminution of the amount of lime from that originally present in the juice amounting to almost 74 percent.

The sodium carbonate alone also removed considerable magnesia from the juice; the original contained .72 gram of the magnesium oxide per liter, which after clarification dropped to .535 gram, a removal of 26 percent. Lime in increasing amounts effected a corresponding increase of the removal of magnesia from the juice; .25 of a gram of lime diminished the magnesia content

\* Bulletin 21, Experiment Station, H. S. P. A. Agricultural and Chemical Series, page 28.

† Cane Sugar and its Manufacture, page 143.

‡ Beet Sugar Manufacture and Refining, Vol. II, p. 347.



by 11.8 percent, and 1.25 grams of lime by 36 percent. The addition of sodium carbonate to lime for clarification worked a further reduction in this respect. It will be noticed in the accompanying diagram that the phosphoric acid and magnesia content vary almost uniformly, signifying that a removal of phosphoric acid implies a removal of magnesia.

In Table XII the results are collected to show the relationships corresponding to Table IV of the first series.

TABLE XII.

Comparison of Total Mineral Matter Removed and Ash Remaining.

Number	Mineral Matter Removed from 1 liter, grms.	Grams per Liter in Juice			
		Insoluble Ash	Phos. Acid	Lime	Magnesia
11.....	3.397	.626	.033	.236	.422
4.....	2.881	.915	.102	.500	.460
10.....	2.868	.576	.072	.170	.371
9.....	2.217	1.234	.340	.394	.511
8.....	2.162	.839	.283	.229	.502
3.....	1.826	1.932	.516	.535	.547
7.....	1.766	1.470	.554	.382	.512
6.....	1.558	.892	.638	.310	.514
12.....	1.229	1.094	.821	.208	.535
5.....	1.122	1.966	.835	.603	.588
2.....	1.047	2.611	.896	.656	.584
1.....	.458	3.100	1.222	.691	.635

The same regularity in the whole series as regards descending mineral matter removed and ascending insoluble ash, as observed in the first series, did not result in the second. If, however, each lot receiving the same amount of lime is regarded separately, as tests 1, 5, and 6; 2, 7, and 8; 3, 9, and 10, and 4 and 11, the changes are uniform. The phosphoric acid and magnesia contents of the juice, however, decrease regularly as the amount of mineral matter removed increases. The lime, as may be expected, varies considerably. Thus in test 4, receiving an amount of lime considerably in excess of that required to produce alkalinity, a large proportion of the phosphoric acid was precipitated, and a considerable amount of mineral matter removed. But the juice



still retained an undesirable quantity of lime. When, in addition to this lime, sodium carbonate was supplied, as in test 11, along with an increase in the mineral matter removed is observed a drop in insoluble ash, phosphoric acid, lime, and magnesia, that in phosphoric acid and lime being very considerable.

The analysis of the mineral matter removed is given in Table XIII, and shows more distinctly the relations between the total amount removed and the elements composing them.

TABLE XIII.

Grams of Mineral Matter Removed from a Liter of Juice.

Number	Total Weight	Phosphoric Acid	Lime	Magnesia
11.....	3.397	1.350	1.585	.308
4.....	2.881	1.295	1.315	.222
10.....	2.868	1.303	1.197	.353
9.....	2.217	1.030	.943	.182
8.....	2.162	1.074	.898	.222
3.....	1.826	.843	.831	.137
7.....	1.766	.814	.738	.209
6.....	1.558	.735	.593	.201
12.....	1.229	.563	.448	.176
5.....	1.122	.522	.275	.127
2.....	1.047	.469	.456	.106
1.....	.458	.162	.194	.074

In addition to the above, there were small quantities of iron and aluminum oxides, sulphuric acid, and a considerable proportion of the silica originally present in the juice. The mineral matter consists, however, essentially of lime and magnesium phosphate. The imperfection of an acid clarification, as regards the removal of phosphate compounds, is particularly emphasized in this table in tests 1, 2, and 5.

The action of the carbonate of soda will be more clearly seen by reference to the following tables.

TABLE XIV.

Juices Clarified with .25 gram Lime per Liter, Acidity Partly or Entirely Corrected by Sodium Carbonate.

		1	5	6
Percentage Phosphoric Acid removed....		10.5	38.8	53.2
“ Lime “ ....	....*	7.5	52.4	
“ Insoluble Ash “ ....		9.8	42.8	74.1
Proportion of Mineral matter “ ....		1	2.45	3.40

\*Lime increased.

TABLE XV.

Juices Clarified with .5 Gram Lime per Liter, Acidity Corrected by Sodium Carbonate.

		2	7	8
Percentage Phosphoric Acid removed....		34.4	59.4	79.3
“ Lime “ ....	....*	41.4	64.9	
“ Insoluble Ash “ ....		24.1	57.2	75.6
Proportion of Mineral matter “ ....		1	1.69	2.06

\*Lime increased.

TABLE XVI.

Juices Clarified with .75 Gram Lime per Liter and Sodium Carbonate.

		3	9	10
Percentage Phosphoric Acid removed....		62.2	75.1	94.7
“ Lime “ ....		17.9	39.6	73.9
“ Insoluble Ash “ ....		43.8	64.1	83.2
Proportion of Mineral matter “ ....		1	1.21	1.57

TABLE XVII.

Juices Clarified with 1.25 Grams Lime per Liter and Sodium Carbonate.

		4	11
Percentage Phosphoric Acid removed....		92.5	97.6
“ Lime “ ....		23.3	63.8
“ Insoluble Ash “ ....		73.4	81.8
Proportion of Mineral matter “ ....		1	1.18

As the lime used increases, the extra amount of phosphoric acid removed by the sodium carbonate decreases, but the amount of lime removed is considerable. Sodium carbonate alone removed 31.3 percent of the lime in the juice. The same amount of sodium carbonate applied in test 10, where .75 gram of lime were added did a far greater duty, since in addition to the reduction of 73.9 per cent calculated on the lime in the juice, there was removed the lime used in clarification. This remark applies to all the calculations on lime removed, the percentages in all instances being calculated on the amount originally present in the juice.

The amounts of scale possible from the evaporation of the various juices may be judged from Table XVIII.

TABLE XVIII.

Pounds of Phosphate and Sulphate of Lime in 400,000 Gallons of Juice.

	1	2	3	4	5	6
Phosphate .....	4247	4031	3288	742	3706	1905
Sulphate .....	.....	.....	.....	3065	.....	.....
Total .....	4247	4031	3288	3807	3706	1905
	7	8	9	10	11	12
Phosphate .....	2348	1406	2422	524	240	1278
Sulphate .....	.....	.....	.....	688	1593	.....
Total .....	2348	1406	2422	1212	1833	1278

In the first series we had to deal with a juice containing .651 gram of phosphoric acid per liter; in this series the content is 1.365 grams, or over twice as much. Consequently, there is need of a greater amount of lime in order to convert all the phosphoric acid into the corresponding salt. In the first three tests of this series there was left an excess of the phosphoric acid over and above that necessary to combine with all the calcium in the respective juices, calculated to tri-calcic phosphate. As the phosphate salt is far more insoluble than the sulphate, it is reasonable to suppose that principally this compound will deposit first. When sufficient lime is added to remove the phosphoric acid more thoroughly, as in test 4, there is an excess of lime left in the juice over that necessary to combine with the phosphoric acid remaining; this excess of lime can then combine with the sulphuric acid in the juice to form calcium sulphate. The quantity of this latter salt will then depend principally on the amount of sulphuric acid in the juice, and given a sufficient amount, the tendency will be to form sulphate scale. By removing the lime with sodium car-

bonate, along with a partial lessening of the phosphate of lime, is a considerable drop of the sulphate of lime content.

As in the first series, the amount of magnesium phosphate that would be found in scale is not considered, for reasons given at that place, but it is certain that part of the magnesia in the juice would be found in the incrustations. It is recognized in the beet sugar industry that when lime from a magnesian limestone is used in clarification, there is greatly increased tendency towards scale formation.

The best results appear, from an inspection of Table XVIII, to have been obtained in tests 8, 10, and 11, although in the first there is a strong possibility of forming phosphate scale. The amounts of clarifying agents in these tests would be for 1000 gallons of juice:

Test 8: 4.16 pounds lime and 7.9 pounds dry sodium carbonate.

Test 10: 6.25 pounds lime and 11.9 pounds dry sodium carbonate.

Test 11: 10.41 pounds lime and 19.8 pounds dry sodium carbonate.

#### *Advantages of Sodium Carbonate Treatment.*

Sodium carbonate clarification is indicated where a juice contains excessive quantities of sulphuric acid and tends to form troublesome incrustations of calcium sulphate. Lime should be added to neutrality or faint acidity, and the juice made alkaline by sodium carbonate. This latter reagent completes the precipitation of the phosphoric acid, and further, depending on the extent to which it is supplied, removes calcic salts from the juice. The removal of these salts lessens the extent of possible scale formation. It has a further advantage, as much of the trouble found in the working and handling of low grade products is ascribed to the presence of lime and the decomposition products of non-sugars due to the action of lime at high temperatures. Amongst others is the froth-fermentation of molasses, which is most frequently found where the juices have been overlimed. Further, the increase in acidity of the molasses from successive boilings is due to the decomposition of the lime-glucose compounds, lime glucinate, etc., at high temperatures.

*Disadvantages of the Sodium Carbonate Treatment.*

The addition of sodium carbonate will probably increase the work of the filter presses, but as it will produce a sediment which by its nature should permit of easy and complete washing of the scums, this objection may be only apparent. The prime objection is the cost of clarification, which will be materially increased. Whether this increase of cost will be more than compensated for by the saving in labor, wear, and delays due to incrustations on the tubes of the evaporators is a question which can be answered only by trial in the mills presented with this problem.

*Conclusions.*

The general conclusions may be summarized as follows:

The use of sodium carbonate in addition to lime in clarifying juices,—

1. Decreases the amount of insoluble ash in the filtered juice.
2. Decreases the amount of phosphoric acid in the same.
3. Decreases the amount of lime in the same.
4. Increases the amount of mineral matter removed by filtration, or the equivalent of the work of the filter presses in factory operations.
5. In juices of high sulphuric acid content, not enough lime will be left to form a serious lime sulphate scale.
6. Effects a partial removal of magnesia from the juice.
7. Effects a slight increase in organic impurities removed from the juice.
8. Improves the working of after products by removal of calcic salts.
9. On account of the cost of the material, the expense of clarification will be materially increased.





















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